PORT OF CHURCHILL
POTENTIAL FOR DEVELOPMENT

VOLUME II: APPENDICES

Prepared for:

Department of Transport
and
National Harbours Board

Prepared by:

Hedlin, Menzies & Associates Ltd.
and
Gibb, Albery Pullerits & Dickson

January, 1969.

Canada

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APPENDICES

APPENDIX A

PORT OF CHURCHILL
EXTENSION OF THE SHIPPING SEASON
PROBLEMS AND PROSPECTS

Introduction

Under present conditions the effective length of the shipping season at Port Churchill for which insurance is available at normal rates is 82 days -- from about July 26 to about October 15. This is a short period of use for expensive facilities and it is not surprising that there should be a recurring interest in possibilities for extending the shipping season. A review of these possibilities at the present time is appropriate for a number of reasons. Firstly, there is an increasing interest in the possibility of exporting through Hudson Bay, not only greater quantities of wheat but also pulpwood, potash, oil and minerals. Secondly, there has accumulated during the last ten years a great deal of additional information about ice conditions in the Hudson Bay and its approaches as a result of an increasingly extensive programme of observations. And thirdly, there is a trend towards the building of more vessels specially strengthened for navigation in ice as shown by the greatly increased use of such vessels in the St. Lawrence River and Gulf throughout the winter. This Appendix deals with the technical possibilities, aspects and costs of extending the season. The effect on trade and any resulting benefits are covered elsewhere in the report.

Background Information Available

A list of references relating to ice and the conditions along the Hudson Bay Route is given at the end of this Appendix. The more important sources of information are summarized below:

"Ice Conditions and Other Factors Related to the Opening and Closing of Navigation on the Hudson Bay Route" by W.J. Hansen

This paper prepared for the 1949 Annual Meeting of the Hudson Bay Route Association includes a summary of ice conditions in Hudson Strait, Hudson Bay and Churchill Harbour during the period 1929-47 based on the information available at that time.

"Sea Ice Conditions Along the Hudson Bay Route" by C.N. Forward

A scientific study based on information available up to 1954.

"Pilot of Arctic Canada, Vol. 1"

Chapter III entitled "Ice and Navigation in Artic Waters" contains a glossary of a hundred and six terms used to describe ice conditions, a detailed description of the formation and movement of sea ice, recommendations to ships' masters operating in ice and general guidance for navigation in Arctic Waters.

"Labrador and Hudson Bay Pilot"

This contains much of the ice information in the "Pilot of Arctic Canada" plus a summary of ice conditions in Hudson Strait and Hudson Bay.

"Ice - Summary and Analysis - Hudson Bay and Approaches"

These summaries and analyses have been prepared annually since 1963 by the Meteorological Branch of the Department of Transport as part of a complete programme of ice reconnaissance and ice forecasting implemented in 1959. The publications include a general description of the ice growth and break-up and charts of pressure, temperature and ice conditions for specific dates from April 21 to November 19. They also give a descriptive comparison of the ice break-up with that of previous years.

"Aerial Ice Observing and Reconnaissance" and "Ice Observations"

These publications contain the details of individual reconnaissance flights from which the "Ice - Summary and Analysis" booklets have been prepared since 1963. They are more detailed than the latter booklets and date back to 1958.

"Guidance to Merchant Ships Navigating in Ice in Canadian Waters"

This booklet, issued by the Marine Operations Branch, Department of Transport, in 1966 supplements the "Pilot of Arctic Canada". Part II of the booklet gives guidance to merchant ships proceeding to Churchill and includes a summary of recent ice experience.

Reliability of Information

It must be realized that it is only since 1954 that the Meteorological Branch, Department of Transport, has been assigned

the responsibility for ice reconnaissance and ice forecasting. Not until 1959 was a complete programme implemented involving extensive aerial observations and scientifically planned recording of relevant metereological data.

At the present time ice reconnaissance for the Churchill route is made by fixed wing shore-based aircraft operating from Frobisher Bay and Churchill, supplemented by ship-based helicopters. The coverage and frequency of observations appear to be adequate, but the accuracy of the observations must inevitably be related to the skill of the observer. It seems unfortunate, therefore, if our information is correct, that ice observers should serve on the average only about three years and that they should be transferred to other duties at a time when their experience and judgement is maturing.

Until the late fifties most of the information about ice conditions along the Hudson Bay route was obtained from the Masters of icebreakers and merchant vessels. This meant that little information was available outside the normal shipping season and that no overall picture of ice conditions was available at any one time.

Even with aerial reconnaissance, false conclusions may be drawn if the period of observation is too short. For instance, the Labrador and Hudson Bay Pilot states that "Aerial reconnaissance during the years 1957-1959 has shown that the first open lead occurred along the southern slope of Hudson Strait and that the bodily movements of the pack have been to the northward". This has not generally been the case in subsequent years, and prevailing north-westerly winds

have tended to move the pack southwards, particularly over the western half of the Strait.

Observing And Reconnaissance

In addition to the background information available, Masters of vessels have ready access to up-to-date information about ice conditions through the elaborate services now provided by the Marine Operations and Meteorological Branches of the Department of Transport. These are described in an official publication and may be summarized as follows:

Ice Information at Churchill

An ice operations officer is stationed at Churchill to give information when conditions warrant. A "suggested shipping track will usually be broadcast daily from Churchill, Nottingham Island, Cape Hope's Advance and Resolution Island. Before leaving Churchill, Masters will be provided with latest ice charts and other information."

Ice Reconnaissance

Fixed wing aircraft, normally based at Frobisher Bay and Churchill, make regular flights from about June 15 onwards. These observations are supplemented by helicopters based on D.O.T. vessels and carrying trained ice observers.

Field Ice Forecast Office at Frobisher

During the navigation season daily bulletins of observed and forecast ice conditions are issued and broadcast by Marine Radio

Stations at Frobisher, Resolution Island, Nottingham Island and Churchill.

Charts showing actual ice observations, estimated present conditions and forecast ice conditions as well as barometric pressure are broadcast in facsimile from Frobisher.

Long Range Ice Forecasts

In view of the variability of ice conditions from year to year it would obviously be helpful to shipping if long range forecasts - about two months ahead - could be made with fair accuracy. It would then be possible to fix opening and closing dates for various classes of vessels operating on the Hudson Bay route according to forecast conditions. This would be preferable to fixed dates which inevitably result in lost opportunities during favourable seasons and delays when conditions are unusually bad. What, then, are the prospects for reliable long-range forecasts?

Long range forecasts are, in fact, being made in Halifax by "Ice Forecasting Central", Meteorological Branch, Department of Transport. The "1968 Seasonal Outlook of Ice Conditions in Northern Canadian Waters", published in May, gives the "Outlook" for the rest of the season. It is based on data from satellite observations, reconnaissance flights during May 13 to 18, the thirty day weather outlook prepared by the United States Weather Bureau, ice thickness reports and weather reports received during the winter. It is emphasized that the "Outlook" is not intended for actual operations, but is prepared only to assist

planning. The "Outlook" forecast ice conditions in late July 1968 somewhat more favourable than recorded for July 23 of 1963, 1964 or 1965 and somewhat similar to July 23 of 1966. In the event, the forecast of general favourableness was correct but the location of the remaining ice was significantly different.

There is as yet insufficient evidence to draw firm conclusions about the accuracy and value of long range ice forecasts. It seems reasonable to expect, nevertheless, that the general severity or mildness of future ice conditions can be forecast six to eight weeks ahead, based on recent measurements of ice thickness, air and water temperatures and general meteorological data. The location and concentrations of ice along shipping lanes will, however, depend more than anything on the strength, direction and temperature of winds during the days immediately preceding the passage of vessels. Such winds cannot be predicted with any degree of certainty more than a week ahead and, until weather forecasting becomes more accurate, it will not be possible to make reliable ice forecasts.

Climate of Hudson Strait and Hudson Bay

The climate of Hudson Strait and Hudson Bay is described in detail in various official publications[1 and 2]. Here will be given only that information which relates to ice conditions and navigation,

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[1]"Labrador and Hudson Bay Pilot", 1965, Canadian Hydrographic Service.

[2]"The Climate of Arctic Canada", Metrological Branch, Department of Transport, 1967.

particularly during an extended shipping season.

Temperature

The normal mean monthly air temperatures measured at representative stations are given in Table A.1 and the average for the Strait and the Bay are shown graphically in Figure A.1. Although not truly representative, Coral Harbour and Frobisher Bay are included for relating to the ice thickness measurements at these stations and discussed later. The location of the stations are shown in Figure A.2.

The significant points to note are as follows: Firstly, on the average, freezing air temperatures (below 28.6 degrees Fahrenheit for sea water) begin about the second week of October and thawing air temperatures begin about the last week of May. Secondly, due to the moderating effect of Atlantic air, the temperatures in the Strait are less extreme than those in the Bay. This can also be illustrated in terms of degree-days of freezing and thawing. From Table A.2 it can be seen that, based on the freezing of sea water at 28.6 degrees Fahrenheit there are normally about 4708 degree-days of freezing in the Strait compared with 6025 in the Bay. The respective degree-days of thawing are 1219 and 1877.

Wind

The strength and direction of the wind is of interest mainly in its effect on the movement of ice during the breakup period. It may also be of importance when considering any changes or additions to facilities at the Port of Churchill.

Although gales may occur during any month of the year, winds

TABLE A.1

MEAN MONTHLY AIR TEMPERATURE IN ^{o}F

Location	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Resolution Island	- 0.6	- 1.2	6.7	15.0	26.7	33.4	37.4	38.2	35.0	28.8	21.4	9.0
2. Cape Hopes Advance	- 7.0	- 8.0	- 0.4	10.6	24.9	35.0	42.2	42.3	36.4	28.7	19.6	6.6
3. Nottingham Island	-13.8	-14.4	- 4.2	8.9	24.5	35.0	42.2	42.0	34.7	25.9	11.8	- 2.7
4. Chesterfield Inlet	-25.6	-25.8	-15.2	1.4	20.7	36.6	48.0	46.9	37.2	22.2	-0.4	-15.8
5. Churchill	-17.3	-16.7	- 4.4	10.6	28.4	42.4	54.7	53.0	43.1	29.6	9.6	- 9.1
6. Port Harrison	-14.8	-16.2	- 5.6	11.2	28.2	38.6	46.8	46.6	40.7	31.1	17.3	- 1.2
7. Coral Harbour	-22.9	-22.6	-11.3	1.1	19.3	35.0	45.9	45.0	32.4	17.1	3.1	-13.8
8. Frobisher	-14.9	-12.7	- 6.1	8.3	28.0	39.0	46.6	44.6	36.8	23.0	7.2	- 7.0
Average-Hudson Strait - 1, 2 & 3	- 7.1	- 7.9	0.7	11.5	26.0	34.5	40.6	40.8	35.4	27.8	17.6	4.3
Average-North Half of Hudson Bay - 3, 4, 5 & 6	-17.9	-18.3	- 7.3	8.0	25.4	38.1	47.9	47.1	38.9	27.2	9.6	- 7.2
Average-Ice Thickness Stations - 4, 5, 7 & 8	-20.2	-19.4	- 9.2	5.3	24.1	38.2	48.8	47.6	37.4	23.0	4.8	-11.4
Degree Days below 28.6^{o}F	-1512	-1344	-1172	-705	-140					-174	-714	-1240
Cumulative Degree Days	3640	4984	6156	6761	6901					-174	888	2128

Source: Labrador and Hudson Bay Pilot.

Note: Coral Harbour omitted from average for North Half Hudson Bay so as not to weight northern boundary with three stations as opposed to two stations for Central Bay.

MEAN MONTHLY AIR TEMPERATURES

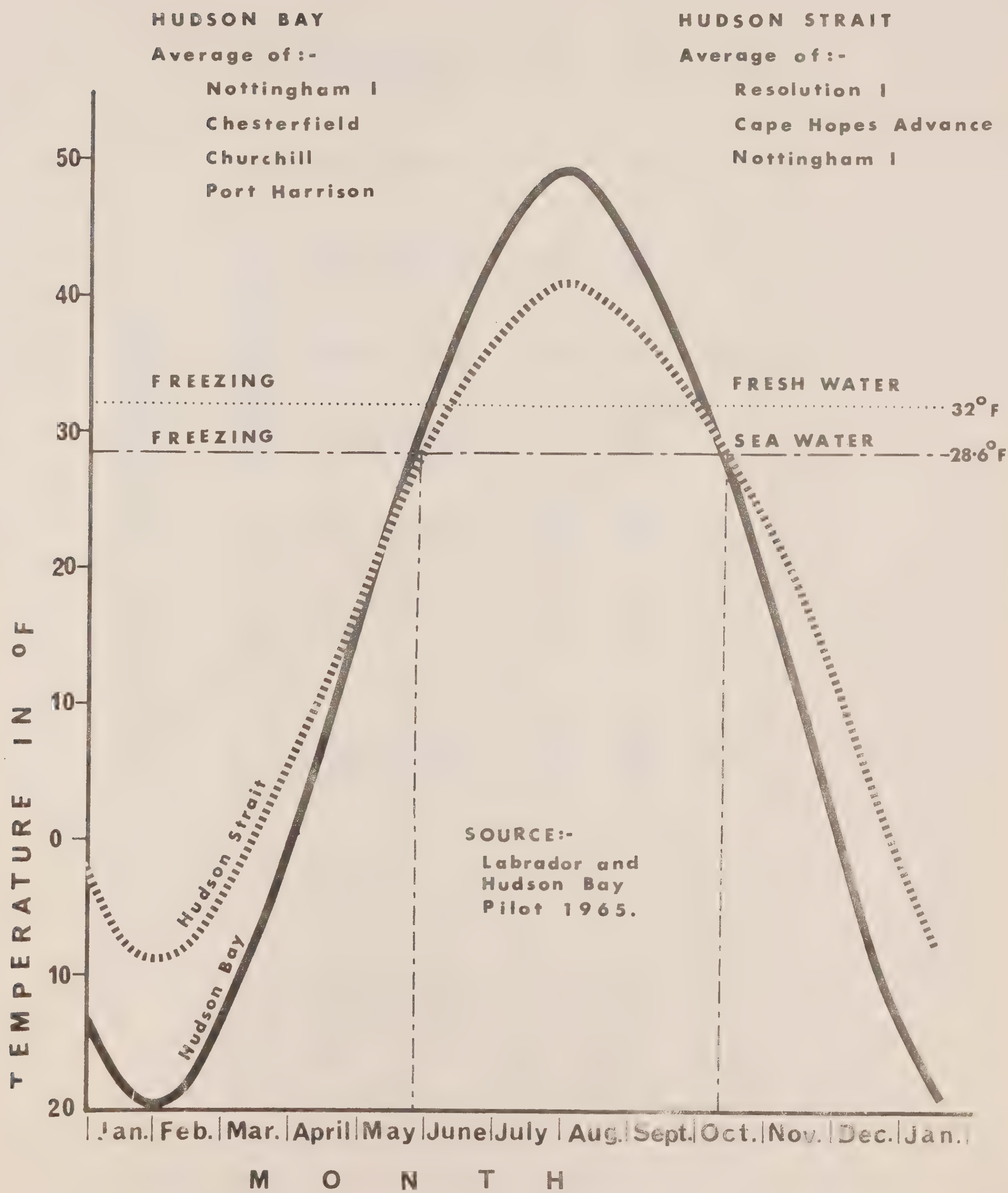

FIGURE A1

TABLE A.2

NORMAL DEGREE-DAYS OF FREEZING AND THAWING
BASED ON 32°F. AVERAGES ADJUSTED TO 28.6°F

Location	Freezing Total	Melting May	June	July	Aug.	Sept.	Oct.	Total
1. Resolution Island	4522	0	50	180	190	90	15	525
2. Cape Hope's Advance	5456	0	120	335	330	145	10	940
3. Nottingham Island	6547	0	130	335	325	110	0	900
4. Chesterfield Inlet	8819	0	160	495	475	165	0	1295
5. Churchill	6616	15	315	670	650	310	20	1980
6. Port Harrison	6028	15	240	495	475	270	30	1525
7. Coral Harbour	8519	0	145	465	425	80	0	1115
8. Frobisher	6961	10	210	440	385	135	0	1180
Average-Hudson Strait								
1, 2 & 3	5508	0	100	283	282	115	8	788
Adjusted to 28.6°F	4708	7	195	388	387	217	25	1219
Average-N. Hudson Bay								
3, 4, 5 & 6	6802	7	211	499	481	214	12	1425
Adjusted to 28.6°F	6025	19	313	604	586	316	39	1877
Average-Ice Thickness								
Stations 4, 5, 7 & 8	7729	6	207	517	484	172	5	1392
Adjusted to 28.6°F	6952	18	309	622	589	274	32	1844

are relatively light during the three months of ice breakup, May, June and July. During these months there is no marked prevalence of wind from any one direction in Hudson Strait. Generally speaking the winds tend to range over the northerly half of the compass from East to West. In the centre of the Strait near Cape Hope's Advance, northwesterly winds predominate.

In Table A.3 are shown some of the major features of the winds at the Port of Churchill. It should be noted, in particular, that, during the navigation season and any likely period of extension, strong winds are predominately from the WNW, NW and NNW. Strong winds from the NE into the harbour entrance are rare.

Fog

The main area where fog adds to the navigational hazard is in the Hudson Strait, particularly at the east end where icebergs and growlers are more prevalent. A recent publication[3] gives the following frequency for fog at Nottingham Island and Resolution Island as defined by the number of days visibility is less than 5/8 mile.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Nottingham Is.	2	1	1	1	5	8	9	10	6	4	-	1
Resolution Is.	2	1	1	2	7	13	16	20	12	4	1	-

Fog is common during the present shipping season, particularly during August. Any extension of the shipping season would be into months with less fog and, in the case of November, with practically no fog.

Blowing Snow

In contrast to fog, blowing snow occurs mainly outside the

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[3] Ibid.

TABLE A.3

MEAN MONTHLY WIND SPEED FREQUENCY IN HOURS PER MONTH AT CHURCHILL

A. TOTAL FREQUENCY FROM ALL DIRECTIONS

Speed mph	Calm	1-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47-54	55-63	64-75	Total Hours	Mean Speed
January	12.4	13.6	55.8	164.	272.	123.	71.2	23.1	6.5	2.0	0.4		744	16.1
February	14.3	16.2	60.3	163.	224.	105.	67.3	21.7	4.4	0.2			677	15.5
March	18.9	21.6	80.1	200.	257.	102.	51.0	11.9	1.9	0.2			744	14.2
April	16.7	14.6	65.9	157.	257.	133.	58.0	15.8	2.2				720	15.3
May	13.7	19.0	86.3	181.	254.	118.	50.1	18.0	3.7	0.4			744	14.7
June	18.0	16.0	104.	204.	227.	102.	40.0	6.3	2.4	0.2			720	13.5
July	16.6	24.4	123.	221.	234.	86.2	32.7	5.0	0.6				744	12.7
August	16.7	27.2	110.	223.	218.	88.1	44.9	14.8	1.7				744	13.3
September	13.1	16.8	77.9	153.	205.	138.	82.8	25.7	4.9	0.7	1.2	0.9	720	16.2
October	12.3	15.2	84.6	159.	206.	141.	89.4	27.8	7.4	1.1			744	16.3
November	12.0	16.3	73.6	154.	210.	120.	84.3	36.3	11.1	2.1	0.3		720	16.6
December	10.4	13.7	69.6	193.	261.	118.	60.8	13.5	3.6				744	15.0

Source: Hourly Data Summaries No. 15, October 30, 1967, Met. Branch D.O.T.

TABLE A.3 (Continued)

MEAN MONTHLY WIND SPEED FREQUENCY IN HOURS PER MONTH AT CHURCHILL

B. FREQUENCIES FROM WNW/NW/NNW

Speed mph	Calm	1-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47-54	55-63	64-75	Total Hours	Mean Speed
June	-	4.3	27.3	51.5	60.9	26.6	13.3	1.3	0.2				185	14.0
July	-	6.0	26.9	43.1	52.4	21.7	12.4	2.3	0.4				165	13.9
August	-	7.2	33.9	62.9	67.2	29.8	17.7	6.1	0.2				225	14.2
September	-	4.3	19.0	31.8	69.9	60.7	44.6	17.3	3.7	0.3	0.4		249	19.3
October	-	2.9	15.1	30.3	66.0	59.6	50.7	22.2	4.0	0.6			251	20.2
November	-	2.3	11.5	36.5	91.4	73.7	55.2	26.0	7.4	0.4	0.1		304	20.4

Source: Hourly Data Summaries No. 15, October 30, 1967, Met. Branch D.O.T.

TABLE A.3 (Continued)

MEAN MONTHLY WIND SPEED FREQUENCY IN HOURS PER MONTH AT CHURCHILL

C. FREQUENCIES FROM NNE/NE/ENE

Speed mph	Calm	1-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47-54	55-63	64-75	Total Hours	Mean Speed
June	-	5.2	29.5	51.8	53.8	17.0	3.2						160	12.2
July	-	6.5	37.3	48.8	39.6	11.5	5.2	0.3					149	11.5
August	-	7.6	26.6	44.9	22.8	9.4	66.7	2.5	0.7				111	12.1
September	-	3.1	18.0	22.0	23.2	11.2	10.6	3.0	0.4	0.2	0.2	0.1	87	15.4
October	-	2.3	10.0	20.7	27.7	15.0	5.5	0.6	0.6				82	14.8
November	-	2.5	8.6	13.8	17.4	10.7	5.6	5.1	2.3	1.0	0.2		67	17.6

Source: Hourly Data Summaries No. 15, October 30, 1967, Met. Branch D.O.T.

present shipping season. The same publication gives the following frequency for Hudson Strait, as defined by the number of days visibility is less than 6 miles.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Nottingham Is.	9	12	5	6	3	1	0	0	1	4	8	10
Resolution Is.	9	9	8	6	2	0	0	0	0	4	12	15

At Churchill the worst months for blowing snow are January, November and December, in that order.

As defined above, with a visibility up to six miles, blowing snow is not likely to be a frequent hazard to shipping. In November, however, it may be accompanied by the rapid formation of slush ice on the surface of the sea.

The Formation and Behaviour of Sea Ice

Due to the effect of salinity on the freezing point and density of water there are substantial differences between sea ice and fresh water ice.

Fresh water freezes at 32°F and has a maximum density at 39.2°F. Once the surface layer of fresh water has been cooled to 39.2°F, subsequent further cooling makes it lighter than the water below so that it stays on the surface and readily turns to ice as soon as it is cooled below 32°F.

Sea water of average salinity freezes at about 28.6°F but more important is the fact that its temperature of maximum density is lower than the freezing point. This means that as the surface water is

cooled, it always tends to sink and be replaced by warmer water. In theory this would mean that the whole mass of water would have to cool to 28.6^{o}F before any ice could form and the whole mass would then tend to freeze solid. In practice this does not happen, because the convection or mixing process is not sufficiently rapid, and because the latent heat of fusion of ice prevents the sudden freezing of a large mass.

What happens in fact, is that very cold weather, particularly with strong winds, rapidly cools the surface layer until ice crystals or "spicules" form. These increase in number until the sea is covered with "slush" of a thick soupy consistency and having an opaque oily appearance. Except in still sheltered water where even sheets of "black" ice may form, the slush tends to break up into separate masses and frequently to form "pancakes" with raised edges as a result of collision between the masses.

The initial growth of sea ice can be very rapid, perhaps 3 or 4 inches in the first 24 hours and 2 or 3 more in the second 24 hours. The insulation then provided, aided by any snow cover, reduces the further rate of growth so that first year or winter ice seldom exceeds 4 to 6 feet.

The ice crystals are non-saline and the salt which has been rejected forms a locally more-concentrated brine. If the formation of sea ice is fairly rapid, the brine becomes trapped between the crystals so that first-year ice normally has an overall salinity of from 4 per cent to 15 per cent.

Because of its method of formation and the entrapped brine, first-year sea ice is weaker than fresh water ice. It also becomes "rotten" and melts more quickly during breakup.

If first-year ice does not melt completely in one year it lives on to become polar ice. In the meantime much of the brine has been leached out and replaced by frozen fresh water from ice or snow which has melted on the surface and filtered down during the summer. Polar ice is therefore stronger and harder than first-year ice. After a second winter it may be up to 8 feet thick.

Apart from its strength and basic thickness the essential feature of sea ice (other than fast ice stuck to the shore) is that it is always moving under the effect of winds, waves and currents. It is frequently being broken up into floes of various sizes by swells or waves and the resulting conglomeration of floes or ice pack is continually being moved around by winds and currents. Over large areas wind forces can be very great and resulting pressures force the ice up into ridges or cause floes to break and ride over one another, a process known as rafting. By the end of winter first year ice (other than fast ice) is usually extensively ridged or rafted. Ridged ice is typically 10 to 20 feet thick but may be occassionally 50 feet thick or more.

Initial and early forms of ice, such as frazil crystals, slush, pancake ice and ice rind are known as NEW ice. Ice which has become a level sheet and obtained a thickness of 2 to 6 inches is known as YOUNG ice. Ice from 6 to 12 inches thick is called MEDIUM WINTER ice and all thicker first-year ice is called THICK WINTER ice.

Very heavy sea-ice of more than one winters growth is known as POLAR ice. This is subdivided into YOUNG POLAR ice in its second winter and ARCTIC PACK of more than two years growth.

Once winter ice has formed, it will usually remain in floes with concentrations of nine tenths or more during the winter period of continuous freezing. Due to movement, ice (which is not fast) will always have some cracks or leads and numerous lines of weakness where cracks have occurred and refrozen. During the winter freezing period the proportion of big floes will be at its greatest.

When thawing takes place the big floes gradually break up and the proportions of small floes, ice cake and brash increase. The surface melting of the floes creates numerous puddles some of which become thaw holes. The entrapped brine hastens the internal melting of the ice which eventually becomes rotten and disintegrates.

As the thawing process reduces the size of the floes there is an interplay between the concentration of the ice pack and the amount of open water. The effect of winds and currents may maintain or re-create high concentrations of ice in certain areas and may drive the ice pack back into areas which had previously become open water. Aerial reconnaissance during the past ten years has done much to establish the trend of ice movements during breakup and the relationship of such movements to wind direction.

Other forms of ice encountered at sea are icebergs and growlers. Icebergs are large masses of floating ice broken off from the fronts of glaciers. (Thousands of bergs are calved annually by

the glaciers of western Greenland and make their way southward through Davis Strait. Most of them continue on towards Newfoundland but some pass into Hudson Strait). Small icebergs about the size of a cottage are known as "Bergy Bits". Growlers are chunks of ice about the size of a grand piano which may be the remains of icebergs or polar floes.

Ice Conditions on the Hudson Bay Route

Ice Conditions in Churchill Harbour

Ice first becomes a problem to shipping in the Harbour when large quantities of frazil ice and pancake ice brought down by the river accumulate in the harbour to considerable depths. The heavy slush so formed combined with the fast ebb tide current past the face of the wharf eventually makes it impossible to maintain vessels at their moorings or manoeuvre them safely, with the result that the harbour is forced to close.

The closing date over the period 1928 to 1967 has varied from as early as October 10th to as late as November 13th with the average date October 25th.

About the same time surface ice begins to form in the harbour and on the layer of relatively fresh water outside the harbour. The Churchill River has been frozen right across as early as November 3rd and as late as November 25th. There has usually been ice packed close to the horizon outside the harbour a few days before the river freezes over. The growth of the ice thickness, based on

measurements taken opposite the wharf is shown on Figure A.3. The breakup of the ice in the river over the period 1928 to 1967 has ranged from May 27th to June 21st with an average date of June 12th. Whilst the breakup opens the harbour, its effective use by shipping depends on ice conditions in Hudson Strait and Bay.

Ice Conditions in Hudson Bay

Ice in Hudson Bay consists almost entirely of first year winter ice. Very rarely will polar ice from Foxe Basin drfit as far west as Coats Island and Mansel Island in the northeast corner of the Bay. The growth of ice begins in the north of the Bay, usually early in November, and gradually spreads southwards. The ice forms more quickly along the west shore of the Bay and usually affects Churchill about mid-November, whilst the centre and south-east areas of the Bay may remain open for some weeks longer. Aerial reconnaisance during the last several years has dispelled the myth that the centre of Hudson Bay remains open.

The pattern of initial growth of ice for the years 1963 to 1967 is shown in Figure A.5.

There have been no consistent measurements of ice thickness in the Bay, but, based on measurements at shore stations (Figure A.4) and allowing, where necessary for differences in salinity, it would be reasonable to assume that the maximum winter thickness, where not ridged or rafted, would vary from four to six feet, depending on the location and the severity of the winter. The extent of ridging is

usually about 2 to 4 tenths of the area.

Thawing and breakup begins most years about the middle of May. Ice concentrations less than nine tenths usually appear towards the end of May and significant areas of open water appear about the same time. Puddles also appear about the end of May and by the middle of June cover about 30 per cent of the ice area. The big and giant flows break up and are not normally observed after the beginning of July.

The prevailing winds are generally from a northerly direction so that the earliest large area of open water appears on the north side of the Bay. By the last week of July there is usually an open water route between Hudson Strait and Churchill along a northerly arc. However, areas of ice protruding northwards from the main pack often interrupt the direct shipping lane until sometime in August. In particular a pack of ice tends to linger in an area centred about eighty miles northeast of Churchill.

The pattern of the breakup for the years 1963 to 1967 inclusive is shown in Figure A.6.

Ice Conditions in Hudson Strait

Ice in Hudson Strait is predominately first year winter ice. Some polar ice may enter from Davis Strait at the eastern end and from Foxe Channel at the western end. The proportion of polar ice in any area is not normally more than 10 per cent but, as happened in the autumn of 1965 proportions over 40 per cent, may occasionally occur at the

western end of the Strait.

Some of the icebergs which drift southward from Davis Strait are carried by currents into Hudson Strait and along the north side as far as Big Island. Those bergs that have not grounded, calved or melted then cross over to the south side and drift eastward towards Cape Chidley. Occasionally, a few bergs drift westward as far as Cape Dorset and very rarely have crossed Foxe Channel into Hudson Bay.

Ice usually starts to form in the Strait about the middle of November. From Figure A.5 it can be seen that, of the five years, 1963 to 1967, in four out of five years the Strait was still completely open on November 5th and in two out of five years was open on November 19th. In the other three years on November 19th the ice in the strait was still generally classified as young ice with a defined thickness of less than six inches. Observations indicate that the worst ice conditions during November are likely to be at the western approach to the Strait in the area bounded by the Bell Peninsula, Coats Island, Mansel Island and Nottingham Island.

Measurements at the shore stations of Churchill, Chesterfield Inlet, Coral Harbour and Frobisher suggest that the maximum thickness of first year winter ice in the Strait is likely to be about the same as in the Bay, - i.e. about four to six feet. The main difference will be in the presence of a small proportion of polar ice in the Strait. Ridging is extensive and occurs over from 2 to 5 tenths of the area.

Thawing and break-up in the strait usually begins at the beginning of May when ice concentrations less than nine-tenths are

first observed. Significant areas of open water appear during the last half of May or beginning of June. Puddles appear at the end of May and usually cover three tenths of the ice area by the middle of June. The big floes break up and are no longer observed after early July.

The prevailing winds are generally from a northerly direction during the breakup period and the first large areas of open water usually appear along the north side of the Strait. This happened during the years 1961 to 1967 inclusive, although during the previous three years years 1958 to 1960, the Strait first opened up along the south side.

The general pattern of breakup for the years 1963 to 1967 is shown in Figure A.6.

Summary of Effect of Ice Conditions Affecting The Shipping Season At Churchill

It can be seen from the above that the opening of the shipping season for unstrengthened merchant vessels is determined by ice conditions in Hudson Strait and Hudson Bay and that Churchill Harbour is open at least 35 days, and on the average 44 days, before the first vessel could normally arrive.

On the other hand, the close of the shipping season is determined by river ice in Churchill Harbour. If we assume November 10th as a reasonable latest safe date for unescorted unstrengthened vessels to pass out of the Strait, Churchill Harbour closes on the

average 13 days and at worst 28 days before shipping would otherwise need to leave.

Possible ways of dealing with the river ice in the harbour are dealt with in a separate Appendix. The prospects for extending the shipping season through Hudson Bay and Hudson Strait depends on the class of ship and the extent of icebreaker assistance. An appraisal of these prospects follows.

Lessons From Winter Navigation In The St. Lawrence

Although ice in the St. Lawrence River is of a different nature and ice in the St. Lawrence Gulf is of a different order of maximum thickness from ice along the Hudson Bay Route, certain comparisons can usefully be made and some things learned.

In the first place the extent of winter shipping in the St. Lawrence has grown to an extent that was difficult to conceive ten years ago. A number of ice-strengthened ships have been put into service in recent years but perhaps more surprising is the large number of unstrengthened vessels that operate in winter with and without ice breaker assistance. Figure A.7 taken from a report[4] on navigation during the 1967 to 1968 winter, shows graphically expansion of traffic since 1960.

In the winter of 1967 to 1968 (December to April inclusive)

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[4]"Navigation During the 1967-68 Winter", Lower St. Lawrence and Gulf Development Association.

a total of 662 vessels reported to "Ice Sydney", of which 273 were ice-strengthened. Of the total only 99 required assistance and it is interesting to note that of these 46 were ice-strengthened. During the two months of relatively severe ice conditions, i.e. February and March 1968, 312 vessels reported of which 156 were ice-strengthened; 74 were assisted, of which 32 were ice-strengthened.

One lesson to be learned from the experience in the St. Lawrence area is that there has been a growing preparedness on the part of shipowners to operate in ice and an increasing use of ice-strengthened ships. This trend could spread to the Hudson Bay route if traffic could be developed to make it commercially worthwhile.

Except for ice jams in the river, which may be formidable, the worst ice conditions in the St. Lawrence and Gulf do not approach in severity the conditions along the Hudson Bay Route. The maximum ice thickness at Nicolet on Lake St. Peter is usually about 30 inches compared with about 60 inches at shore stations in the Hudson Bay area. There is, however, a fair and interesting comparison to be made of the periods of initial ice growth if December, January, and February in the Gulf of St. Lawrence are compared with October, November and December in Hudson Bay and Strait.

The average November temperature in the Hudson Bay and Strait area is very little different from the average January temperature in the Gulf of St. Lawrence area. Ice conditions at the end of these two months in the respective locations might,

therefore, be expected to be reasonably similar on the average. Observations indicate that this is broadly so. It must be remembered, however, that December in the Hudson Bay and Strait area is considerably colder than February in the Gulf of St. Lawrence, with the result that once ice formation has begun, the transition through new, young and medium winter ice to thick winter ice will tend to be more rapid. Neverthless, the capabilities and problems of shipping in the Gulf of St. Lawrence during January give some idea of the potential capabilities and problems of shipping along the Hudson Bay route in November.

<u>The Capabilities and Limitations of Different Classes of Ships In Ice Congested Waters and Their Relationship to Prospects For Extending The Season to Churchill</u>

In the following discussion it is assumed that the problem of river slush ice can be dealt with so that the end of the season is affected only by sea ice.

It is desirable to consider ships and their capabilities under the following categories:

- Unstrengthened merchant vessels, unassisted
- Unstrengthened merchant vessels with icebreaker assistance
- Merchant vessels with bow strengthening (Lloyd's Ice Class 3 or equivalent) unassisted
- As above but with icebreaker assistance
- Merchant vessels with full strengthening (Lloyd's Ice Class 1 or 1* equivalent) unassisted.
- As above but with icebreaker assistance

- Merchant vessels with full strengthening and possible special hull configurations

The above are convenient categories but there are, of course, other important factors, such as the size and power of the vessel, whether laden or light, and the skill and experience of the ship's master.

Unstrengthened Merchant Vessels, Unassisted

Conventional unstrengthened vessels are vulnerable in ice principally for the following reasons: Impact with ice floes may bend or fracture bow plating or framing. If trapped in close packed ice in strong winds, severe pressures may build up sufficient to damage the hull. Unless fitted with special propellers, blades may be broken by striking ice blocks, particularly if the vessel is unladen and high in the water. If the vessel has to go astern, steering gear may be damaged. In addition, sea connections may be damaged and strainers plugged with ice.

Unstrengthened vessels should attempt to navigate in winter ice only if the pack is very open with an average concentration of less than three-tenths and then only at a slow speed up to 5 knots depending on the size of the floes. Small areas of open pack with a concentration up to six-tenths could be negotiated by vessels with adequate power at very slow speeds.

At the beginning of winter when ice is forming, unstrengthened vessels of average size and power could make good progress through continuous young ice up to 4 inches thick. It must be remembered, however, that the initial thickening from young to

winter ice can be very rapid and also that considerable depths of soupy slush can be formed during early season blizzards.

Relating the above to the Hudson Bay Route, a study of Figure A.6 and observations from previous years indicate that July 23rd is a reasonable date for unstrengthened vessels to enter the Strait past Cape Chidley. About two years out of five a slightly earlier date would be possible but the forecasting of exact ice conditions cannot yet be made sufficiently far in advance for advantage to be taken of favourable conditions in a particular year. Figure A.5 and observations from previous years indicate that it would nearly always be safe for vessels to leave Churchill up to November 5th and most years several days later. 1965 was an exceptional year with Foxe Basin ice threatening the shipping lane for much of the season and forming a nucleus for the early growth of winter ice round Mansel Island. The main danger at the end of the season is that an exceptionally rapid freeze up should trap an underpowered vessel in heavy slush or in a rapid change from young to winter ice. All things considered, and with good weather forecasting, November 7th would seem a reasonable latest date for unstrengthened unescorted vessels to leave Churchill on the assumption that icebreaker assistance could be received in an exceptional year such as 1965.

<u>Unstrengthened Vessels with Icebreaker Assistance</u>

Icebreaker escort will improve the capabilities of unstrengthened vessels only to a limited degree in thick winter ice.

The vessel must not follow too close in case the icebreaker is suddenly slowed down by the ice. In consequence there is often time for floes to drift into the lead formed by the icebreaker and to damage the escorted vessel unless slow speed is being maintained. It is therefore, uneconomical and impractical to escort an unstrengthened vessel through very large areas of close pack.

Icebreaker assistance might be a greater value at the end of the shipping season for escort through young or early winter ice at a time when there are no heavy floes in the Bay and only a few isolated polar floes in the Strait. With icebreaker assistance it would be reasonable to advance the opening of the season for unstrengthened vessels by about one week to July 16th and to delay the close of the season by about nine days to November 16th. Thus, if ice conditions in the harbour can be satisfactorily overcome, it would, with icebreaker assistance, be reasonable to expect about a four month season. Experience might show that this could be extended still further, particularly with a convoy system to escort the first vessels inbound to Churchill and the last vessels outbound.

Merchant Vessels with Strengthened Bows, Unassisted

An adequately strengthened bow will enable a vessel with full power to make relatively good progress through winter ice having a concentration of up to six-tenths. The danger of damage to the rest of the hull, if beset in heavy wind-driven pack ice, remains.

A strengthened bow and full power should also allow a

vessel to make fair progress through young and medium winter ice up to 8 inches thick.

Relating these capabilities to the recorded ice conditions it would be reasonable to allow bow-strengthened vessels past Cape Chidley on or after July 16th and to fix November 12th as the last date for leaving Churchill, again assuming, that ice conditions in the harbour are overcome.

Merchant Vessels with Strengthened Bows and with Icebreaker Assistance

Icebreaker assistance would allow vessels with strengthened bows to proceed more quickly through higher concentrations of winter ice. It would also reduce the danger of the vessel becoming beset in very close pack.

It is probable that, as a matter of policy the Department of Transport would not wish to escort other than fully strengthened vessels through substantial areas of nine tenths pack. On this assumption the earliest date for entering Hudson Strait would be about July 9th. The extension of the end of the season is problematical because no ice observations are available beyond November 19th. In view of the strong winds prevalent in December which may endanger a vessel without full strengthening, a reasonable latest date would be November 30th when the sea ice would not normally be more than 18 inches thick.

Vessels with Full Ice Strengthening (Lloyds Ice Class 1 or 1*)

It is assumed that these vessels would be specially designed for ice congested waters and, in addition to having the required strength, would have ample power and other characteristics for efficient operation in ice. A minimum power/displacement ratio of 0.5 has been recommended by the Department of Transport together with a number of other characteristics, listed in Table A.4.

These vessels would be able to make good progress in concentrations of winter ice up to six-tenths and would be able to negotiate moderate areas of close pack. It would probably not be economical to spend time making very slow progress through the large areas of close pack which tend to persist up to the end of June. On this assumption July 9th would seem to be about the earliest reasonable date for fully strengthened vessels to pass Cape Chidley. Pending further observations of the growth of ice, November 15th would seem to be the latest reasonable date for vessels to leave Churchill.

Vessels with Full Ice Strengthening and with Icebreaker Assistance

Since vessels with full ice strengthening have a fair ability of their own to get through winter ice in open pack up to six-tenths, the assumption of icebreaker assistance must imply the need to get through large areas of close pack in concentrations up to about nine-tenths. Alternatively, in the case of unbroken fast ice in harbours, bays, inlets and rivers, it must imply a need to

TABLE A.4

RECOMMENDED CHARACTERISTICS FOR SHIPS OPERATING IN WINTER IN THE GULF OF ST. LAWRENCE

Icebelt grade of steel	- E
Stem	- Steel casting or round bar
Form of bow	- Icebreaking
Stern Ice-knife	- Cast steel
Rudder stock	- 50% increase over Lloyd's Rules for 100 Al.
Propeller shaft	- 50% increase over Lloyd's Rules for 100 Al.
Propeller	- Icebreaking scantlings with 75,000 p.s.i. tensile
Ship side valves	- Steam de-icing
Main engine & generator recirculation	- Sea bays with 100% recirculation
Trimming pump	- Required
Anchor windlass	- De-icing arrangements

Source: Report of pre-winter meeting of Dept. of Transport and Winter Navigation Committee of the Lower St. Lawrence and Gulf Development Association.

break ice which is too thick for the vessel itself to break.

What rate of progress can be made through close pack winter ice or fast ice of a certain thickness will depend on the size and power of the icebreaker. Documented information about the capabilities of icebreakers is scarce but Figure A.8 gives an indication of the relationship between power and breaking ability in sea ice, based on answers to questionnaires and previous data. With a sufficiently powerful icebreaker it would be technically possible to keep the Hudson Bay route open all year round; but there would almost certainly have to be substantial two-way trade to justify not only the cost of a large icebreaker but also the cost of keeping open the harbour at Churchill and maintaining the port facilities under extreme climatic conditions.

Assuming that the Churchill River can economically be diverted above the Harbour (See Appendix B) so that the latter becomes a salt water inlet, it would be possible with icebreaker escort to maintain shipping at least until mid-December when the sea ice would normally be about two feet thick. At the beginning of the season, with a modern icebreaker of adequate power, it would be possible and not unreasonable to escort strengthened ships through the Hudson Strait and Bay from the time that thawing begins and the concentration of ice begins to lessen. This is about mid-May. Thus it would be possible, but not necessarily economical, to obtain a shipping season of about seven months.

Merchant Vessels with Full Strengthening and Special Hull Configurations

During recent years special bow shapes and hull configurations have been suggested which it is claimed are more efficient for forcing a passage through ice than the present bow shapes on icebreakers. One of these is the "Alex-bow" which is shaped somewhat in the form of a plough and breaks the ice by lifting it up rather than by pressing it down, or by a wedging action as is common with existing icebreakers. A small prototype version of the Alex-bow has been tested in ice on Lake Ontario[5] and on Lake Erie. Because of the lack of truly comparable data for conventional icebreakers the results must be considered inconclusive, but there is no doubt that the device holds considerable promise. More recently, it has been proposed that the basic Alex-bow shape should be combined with the hydraulically efficient hammerhead bow now adopted on many large vessels. It is understood that this "Alex-bow-Hammerhead System" has recently undergone extensive model testing in the laboratory in the United Kingdom. The results of these tests when available should give a clear indication of the benefits of the Alex-bow-Hammerhead System in relation to other bow forms, and the ice conditions under which

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[5] "Alexbow Icebreaking Bow Forms" Report on Trials and Development to March 1967. Gilmore, Carman & Milne, Naval Architects, Montreal.

it would be most beneficial.

It is fairly easy to envision the operation of a plowing device through a relatively thin even sheet of ice such as forms on areas of the Great Lakes. There would be an obvious advantage in a device which lifted the ice and pushed it aside on to the adjacent ice sheet thus leaving a clear channel with no ice to damage propellers or interfere with following vessels. However, the ice along the Hudson Bay route is extensively ridged and consists of floes which are generally in a state of constant movement. Forcing a passage through such ice is mainly a matter of exploiting leads and pushing floes aside, and only partly a matter of breaking ice. Where ice has to be broken it must be possible on occasions to break through ridges of considerable depth. It seems, therefore, that a system such as the "Alex-bow-Hammerhead" would have no special advantage on the Hudson Bay route and would, in any case, have to be incorporated on large vessels with ample power. If its efficiency through ice were to be maintained it would seem that the vessel would have to operate at a fairly precise draft which would require that vessels which have little or no cargo in one direction would have to carry adequate ballast.

The extra cost and loss of pay-load of specially designed icebreaking merchant vessels suggests that these would be limited to carrying a special commodity for which there was no other competitive route. Since the percentage extra cost and the percentage

loss of pay-load will be less as the size of the vessel increases, it is probable that such special icebreaking merchant vessels will only be economical if they are of substantial size. This may rule out the use of Churchill as a terminal port, if deeper facilities cannot be provided at an economical cost.

Summary and Remarks

Table A.5 summarizes what would appear to be the reasonable length of shipping season for various categories of vessels with and without icebreaker assistance. It represents a best estimate of possibilities in the light of the information available. Unfortunately this information is far from complete and there is almost a complete lack of scientifically recorded data about the actual performance of merchant ships and icebreakers in various ice conditions. Such figures, as have been published or stated relating power of vessel to thickness of ice, have not always given the speed of progress and have seldom indicated the salinity, temperature or other conditions of the ice.

The lengths of season given in Table A.5 are based on the following assumptions:

- That the vessels should not be exposed to any exceptional risk and should be eligible for insurance at reasonable rates, comparable to those for winter navigation in the Gulf of St. Lawrence.

  That the various classes of vessel under the conditions indicated can make fair progress, averaging not less than half normal speed.

TABLE A.5

LENGTH OF SHIPPING SEASON FOR VARIOUS CLASSES OF SHIPS

Category	Assumed Capability of Vessel or Icebreaker: Opening Concentration of Floes, Tenths	Assumed Capability of Vessel or Icebreaker: Closing Thickness of Unbroken Ice, Inches	Opening Date past Cape Chidley	Closing Date at Port Churchill	Reasonable Effective Length of Season (Days)*
(a) Unstrengthened merchant vessels, unassisted	3 Belts to 6	4 Young Ice	July 23	Nov. 7	107
(b) Unstrengthened vessels with icebreaker assistance	7 Belts to 9	12	July 16	Nov. 16	123
(c) Bow-strengthened vessels, unassisted	6	8	July 16	Nov. 12	119
(d) Bow-strengthened vessels with ice-breaker assistance	7 9 Short Distances	24	July 9	Nov. 30	144
(e) Fully-strengthened vessels, unassisted	7 9 Short Distances	12	July 9	Nov. 16	130
(f) Fully-strengthened vessels with heavy ice-breaker assistance	9	36	May 15	Dec. 15	214
(g) Possible future ice-breaking merchant vessels with special bow and/or hull shapes	Up to 9	Up to 36	July 9 to May 15 depending on power	Nov. 30 to Dec. 15 depending on power	144 to 214

*From opening date at Cape Chidley to closing date at Churchill. Effective season at Churchill about 3 days less.

- That there is an economical solution to the problem of river slush ice which at present fixes the end of the shipping season.

It must also be realized that the lengths of season shown in Table A.5 are considered reasonable only from the technical operational viewpoint. Whether they make economic sense will depend on the volume and type of trade, the competition from other routes, the cost of strengthened vessels, the cost of icebreaker assistance and the cost of any special works at the Port of Churchill. Some aspects of the economic problems are discussed elsewhere in this report.

Of the categories considered, items (f) and (g) are the most difficult to assess because of the lack of data about the capabilities of the vessels concerned and the lack of experience in navigating the Hudson Bay Route during May, June and December. Fundamentally, the practical length of season will depend on the size, strength and power of the icebreakers or icebreaking merchant vessel. With heavy vessels of sufficient power it would theoretically be possible to keep the Hudson Bay Route open twelve months of the year. However, the depth obtainable in Churchill harbour and its approaches will limit the size of vessel and it is doubtful whether it would be economical to pay the high premium for the extra strength and power for all-year operation, except on very large vessels. Such vessels would also have to be carrying a commodity on a route to which there was no competitive alternative. A typical example is iron ore from the north of Baffin Island if

the extra cost of an all-year-round service is less than the cost of the alternative stockpiling. As far as the Hudson Bay is concerned, one potential commodity requiring large vessels is oil. It does not appear, however, that Churchill could be developed economically as a terminal for large tankers. Chesterfield Inlet, with substantial depths close to shore, would appear to offer better possibilities and would, incidentally, provide a shipping route which is shorter by 200 miles and tends to become ice-free at an earlier date.

The suggested maximum season of May 15 to December 15 for classifications (f) and (g) fits in well with the winter season in the St. Lawrence and would enable icebreakers and strengthened merchant vessels to operate in the St. Lawrence River and Gulf when not employed on the Hudson Bay Route.

In spite of the possible inaccuracies that might be incorporated, as explained above, an attempt to indicate and compare probable costs per additional bushel made possible by the alternative approaches is given in Table A.6. The figures quoted refer to 30,000 dwt. vessels carrying 1,150,000 bushels.

Small differences between these figures and those used in the report are due to the use of an "additional time" base instead of spreading the cost throughout a full year. On this basis it would appear that the tidal barrier could offer an attractive advantage, permitting the shipment of an additional 6 million bushels during

the 23-day extension. In terms of the total investment at Churchill (including the railway, town, etc.) of some $70 million; at 5 per cent per year interest, the average cost per bushel would be reduced from the current level of 17.5 cents to 13.4 cents. This would, apparently, more than cover the additional cost of the barrier, if this proved necessary. Table A.6 provides the detail of the cost effect which could result from various combinations of different Port operating seasons, icebreaker assistance, various degrees of vessel strengthening assuming that grain throughput is proportionate to the length of the Port operating season.

TABLE A.6

INCREMENTAL COSTS/BUSHEL OF ALTERNATIVE SCHEMES

	Combination	Port Operating Season	(days) Increase	Bushels/Year 1967 basis (millions) Total[a]	Increase	Additional Costs (¢) per Additional Bushel Tidal Barrier[b]	Vessels[c]	Total Cost On Annual Throughput ¢/bu.
1.	Normal Season	82	-	20	-	-	-	17.5
2.	Tidal Barrier with Unstrengthened Vessels	105	23	26.1	6.1	3.60	-	14.2
3.	Tidal Barrier with Unstrengthened Vessels and St. Lawrence Icebreaker	123	41	30.0	10.0	2.20	4.90	14.0
4.	Tidal Barrier with Bow-strengthened Vessels	119	37	29.1	9.1	2.42	8.90	15.6
5.	Tidal Barrier with Bow-strengthened Vessels and St. Lawrence Icebreaker	144	62	35.2	15.2	1.45	6.80	13.5
6.	Tidal Barrier with fully Strengthened Vessels	130	48	31.8	11.8	1.86	12.00	16.1
7.	Tidal Barrier with fully Strengthened Vessels and St. Lawrence Icebreaker	214	132	52.3	32.3	0.68	7.80	11.9
8.	Tidal Barrier with fully Strengthened Vessels and St. Lawrence Icebreaker	365	283	88.5	68.5	0.32	12.60	14.0

Source: Gibb, Albery Pullerits & Dickson

[a] Pro-rata.

[b] Assumes Cost - $2,930,000 at 7 per cent plus 0.5 per cent maintenance per year.

[c] Assumes 3.6 voyages per year for normal season and 315 day maximum operating year for any vessel.

GROWTH OF ICE IN CHURCHILL HARBOUR

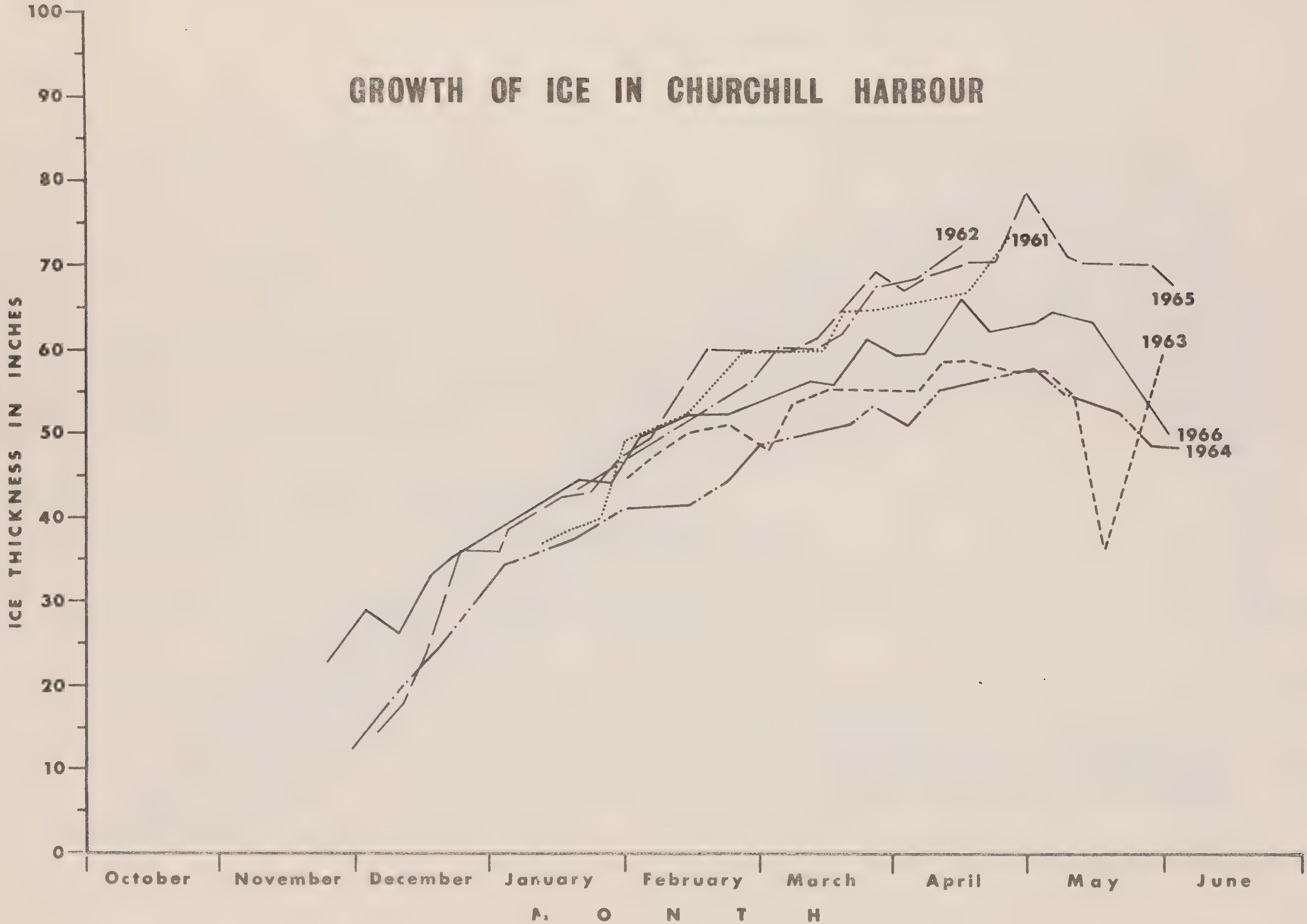


FIGURE A3

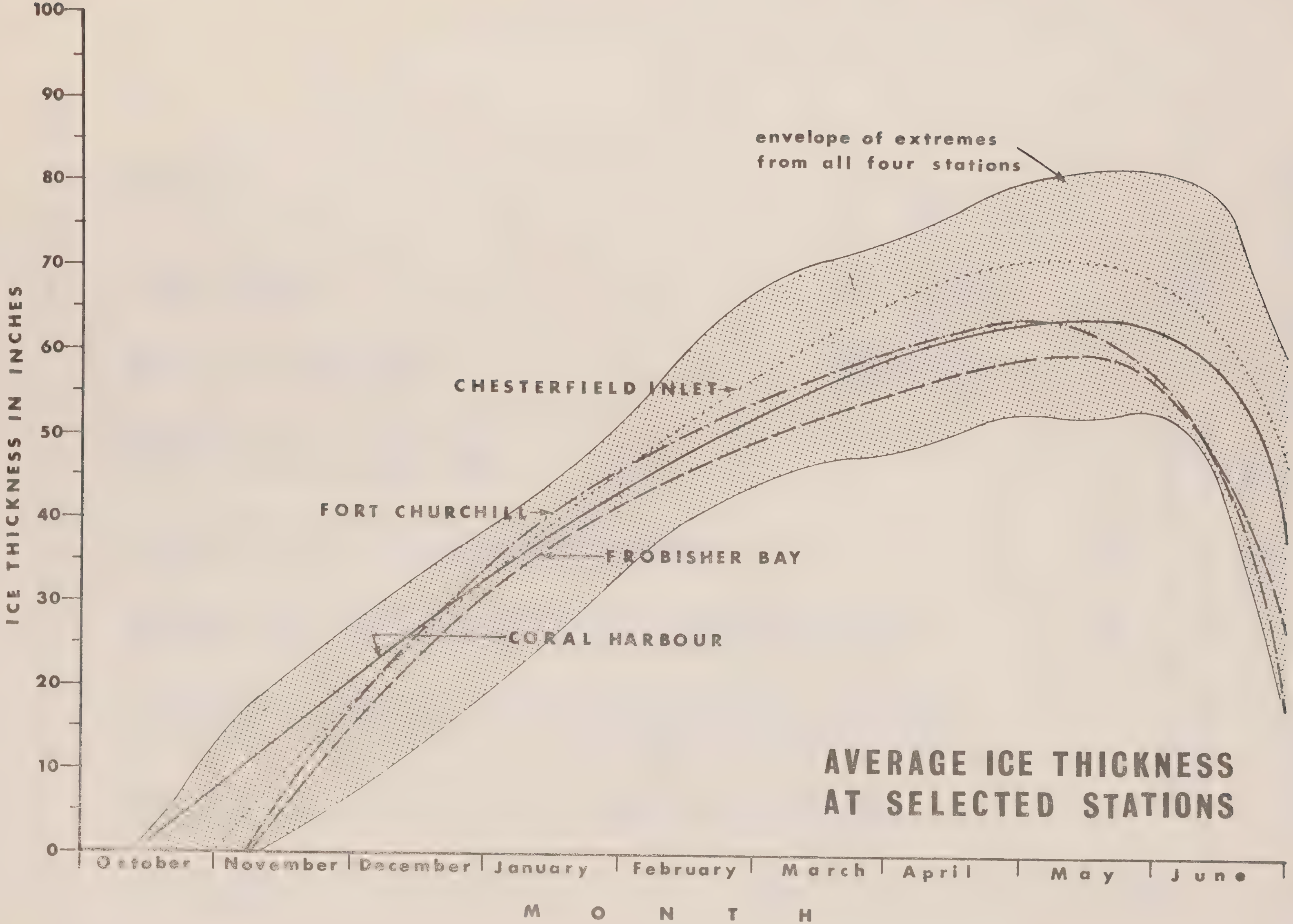
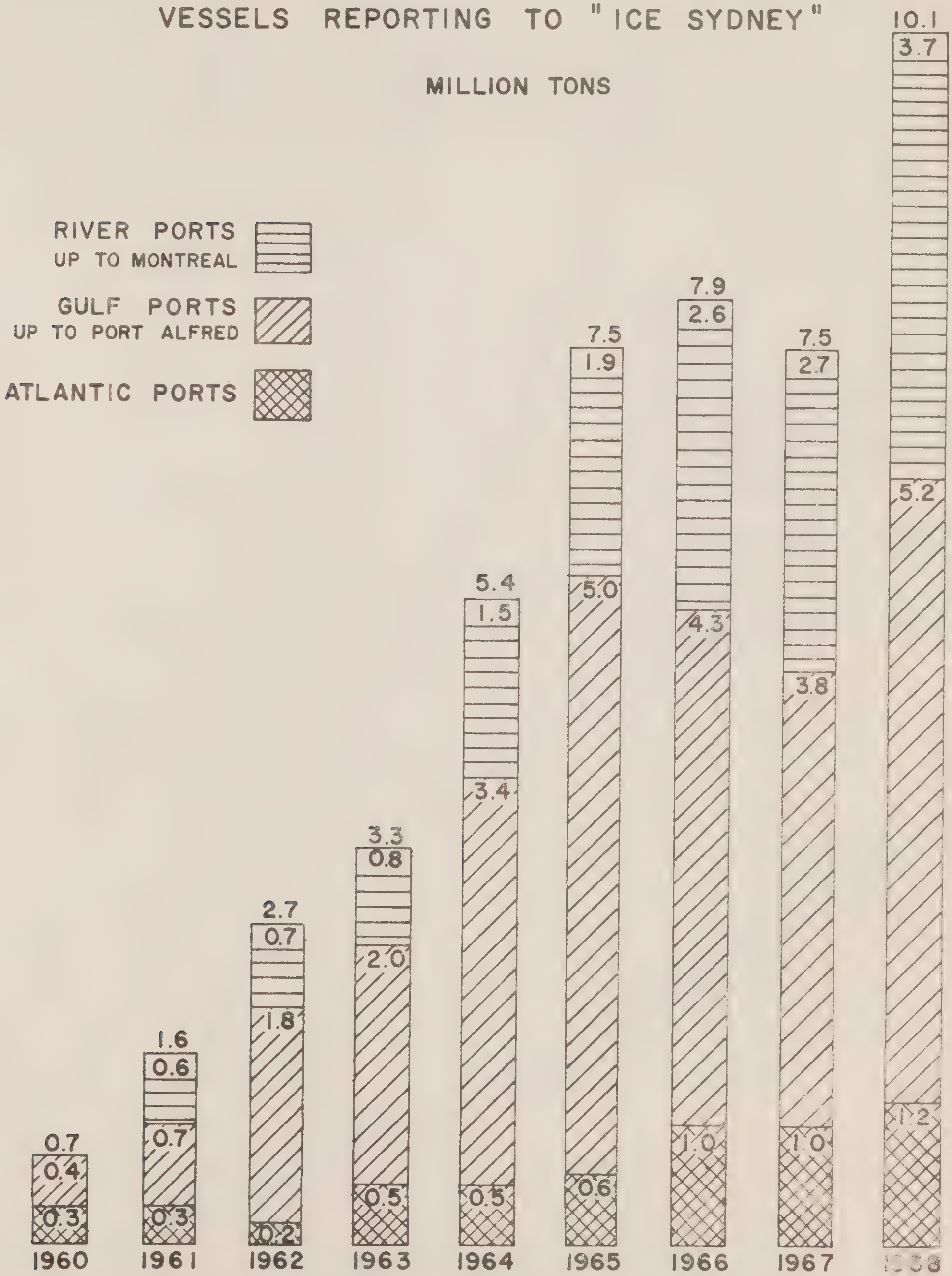

AVERAGE ICE THICKNESS
AT SELECTED STATIONS
envelope of extremes
from all four stations
CHESTERFIELD INLET
FORT CHURCHILL
FROBISHER BAY
CORAL HARBOUR
ICE THICKNESS IN INCHES
100
90
80
70
60
50
40
30
20
10
0
October
November
December
January
February
March
April
May
June
M O N T H

FIGURE A4

WINTER SHIPPING IN THE ST. LAWRENCE RIVER AND GULF

VOLUME OF WINTER CARGOES HANDLED BY VESSELS REPORTING TO "ICE SYDNEY"

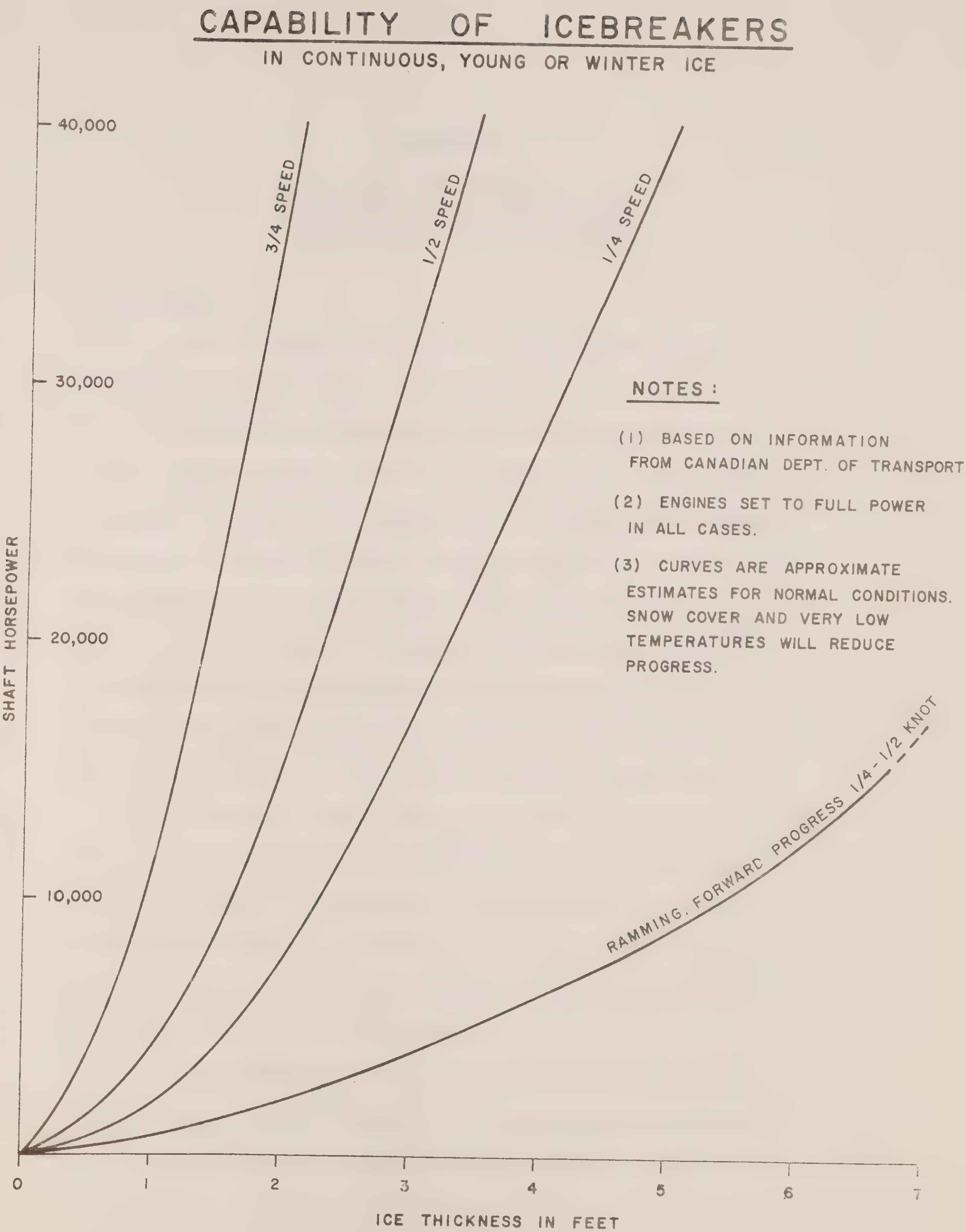
MILLION TONS



PERIOD - DECEMBER 15 TO APRIL 15

SOURCE: "ICE SYDNEY" & LOWER ST. LAWRENCE & GULF DEVELOPMENT ASSOCIATION DATA

FIGURE A7



CAPABILITY OF ICEBREAKERS
IN CONTINUOUS, YOUNG OR WINTER ICE
SHAFT HORSEPOWER
40,000
30,000
20,000
10,000
3/4 SPEED
1/2 SPEED
1/4 SPEED
RAMMING. FORWARD PROGRESS 1/4 - 1/2 KNOT
NOTES:
(1) BASED ON INFORMATION FROM CANADIAN DEPT. OF TRANSPORT.
(2) ENGINES SET TO FULL POWER IN ALL CASES.
(3) CURVES ARE APPROXIMATE ESTIMATES FOR NORMAL CONDITIONS. SNOW COVER AND VERY LOW TEMPERATURES WILL REDUCE PROGRESS.
0
1
2
3
4
5
6
7
ICE THICKNESS IN FEET

FIGURE A8

APPENDIX B

PORT OF CHURCHILL
EXTENSION OF THE SHIPPING SEASON
PROBLEM OF SLUSH ICE IN HARBOUR

Introduction

At the present time, the end of the shipping season is determined by the formation of slush ice in the river and estuary. As winter approaches, the shallow fresh river water cools more rapidly than the deeper salt water in Hudson Bay. During periods of very cold weather with strong winds or blizzards, considerable quantities of frazil ice forms in the river and the estuary. This ice accumulates during the flood tide in the upper part of the estuary and forms a mass of slush ice to a considerable depth. The slush ice then sweeps down on the flood tide and with the strong current along the face of the wharf, it becomes impossible to manoeuvre vessels or maintain them safely at their berths.

The date on which slush ice has forced the closing of the harbour has varied from as early as October 10 to as late as November 13 with the average date being October 25. Presumably because of the hazard represented by the river ice, insurance of vessels at normal rates ends on October 15 but is available at a 25 per cent surcharge until October 20.

The shipping route through Hudson Bay and Hudson Strait does not begin to freeze until about the second week in November and in general, ships can leave Churchill as late as November 7

without being endangered by ice outside the harbour. If, therefore, an economical method could be found of reducing or eliminating the problem of slush ice in the harbour it would be possible to extend the shipping season by about 23 days beyond the present limit of normal insurance and about 13 days beyond the average date on which the harbour is forced to close. This appendix discusses various methods of solving this problem.

Some aspects of the problem have been studied in detail by the National Research Council and discussed in a report[1] entitled, "FEASIBILITY OF EXTENDING NAVIGATION SEASON AT CHURCHILL HARBOUR" dated December, 1966. It is not intended in this appendix to duplicate the studies described in the NRC report. However, comments are made where considered desirable and the schemes considered by the National Research Council are included for the purpose of comparing the costs of various alternatives.

Alternative Schemes

The alternatives which we have studied, including those previously studied by the National Research Council, are as follows:

a) Waiting to see the effect of the diversion of the Churchill River into the Nelson River by Manitoba Hydro. Otherwise no action.

b) Compressed Air Systems and Submersible Pumps

c) Ice Boom

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[1]Dick, T.M. "Feasibility of Extending Navigation Season at Churchill Harbour" National Research Council of Canada. December, 1966.

d) New Channel to Alter Current Distribution

e) Deflecting Groin

f) Complete Protection of Wharf and Turning Basin

g) Diversion of River Above Harbour

h) Tidal Barrier

Of the above alternatives, a), c), d), f), and g) were discussed in the National Research Council report. Our further comments on those and the other alternatives are as follows:

Effect of Diversion of Churchill River by Manitoba Hydro

This question was studied in considerable detail by NRC and their conclusions are reproduced as follows:

> "1. The Churchill River responds to atmospheric cooling more quickly than the sea. Ice production commences in the river in advance of the sea, and it is this ice that brings about closure of the harbour. Snow or blizzard conditions have a marked effect on the river, and bring about heavy slush ice conditions.
>
> 2. Diversion of the river at Southern Indian Lake would greatly reduce the fresh water flow, causing the river to cool more quickly and produce ice sooner; offsetting this, would be the reduction in average river velocity by the flow diversion. The velocity would possibly be reduced to the point where a solid ice cover formed immediately, thus inhibiting frazil ice production.
>
> 3. It is expected that a scheme for diverting the river would cause ice to appear a few days earlier, but the volume of ice should be substantially reduced. Local ice production and snowfall on mud flats would not be affected."

Since the publication of the National Research Council report, we have been advised by the Manitoba Hydro that, under normal

circumstances, the compensation flow to be released from Southern Indian Lake would be in the order of only 500 c.f.s. During the month of October, when ice is forming on the river, the natural flow below Southern Indian Lake might be in the order of only 2000 c.f.s., giving a total flow of about 2500 c.f.s. which is one half that assumed by NRC. Their conclusions may, therefore, apply with even greater force and there is little doubt that the proposed diversion will have a very substantial effect on the amount of ice generated in the river upstream of the estuary. Local ice production due to snowfall over the area of the estuary itself would not be affected but it is unlikely that this is a significant contribution to the present total of slush ice.

Compressed Air Systems and Submersible Pumps

Compressed air systems have been successful in preventing the formation of sheet ice under severe weather conditions provided that certain other conditions are favourable. The chief amongst these other conditions are comparatively still water and an adequate depth and volume of water with a temperature above freezing. At Churchill neither of these two latter conditions exist during winter. In the first place, there is a very strong current past the face of the wharf, and in the second place there is no increase in temperature with depth. In any case the problem at Churchill is not initially one of preventing the formation of

sheet ice but of deflecting large masses of slush ice flowing down with the ebb tide. Local observations indicate that compressed air systems would be of little value unless the current and quantity of slush ice could first be reduced. If this were achieved, however, the slush ice would then no longer endanger shipping, and compressed air systems would serve no purpose except possibly to prevent the formation of sheet ice adjacent to the wharf.

The above conclusion is confirmed by ice control experiments carried out at Churchill in 1965[2].

This experiment involved the use of a submersible electric pump to bring up water from the lower levels, but the scientific principle was the same as with compressed air systems. The experiment showed that due to the absence of an effective thermal reserve in the harbour at Churchill the pump had only a very limited effect which was due to the local turbulence created.

It seems clear that compressed air or similar systems on any reasonable scale cannot be a solution to the slush ice problem at Churchill.

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[2]"Ice Control Experiments - Canadian Arctic" Foundation of Canada Engineering Corp. Ltd., - Bulletin - Permanent International Association of Navigation Congresses, 1967, Vol. 1/11 No. 23/24.

New Channel to Alter Current Distribution

The turning basin opposite the wharf and the approach channel to it are so much deeper than the rest of the harbour that they can carry a large volume of water under a comparatively small hydraulic gradient. This in effect attracts the flow into the turning basin and accentuates the normal current along the face of the wharf.

If a sufficiently large and deep channel were excavated away from the wharf along the centre of the harbour it would attract a large flow and would thereby reduce the flow past the face of the wharf.

A typical scheme was discussed in Section C of the NRC report, and shown in Figure 17 of that report. It is estimated that the NRC scheme would cost $6,020,000 made up as follows:

Channel excavation	$4,600,000
Deflecting Wall	1,420,000
TOTAL	$6,020,000

Ice Boom

An ice boom penetrating the surface of the water to an adequate depth might be used to deflect the slush ice away from the wharf and the turning basin. A suggested design of ice boom was shown in Figure 18 of the NRC report. We have considered a boom in the form of a simple curve as shown in Figure B.2. The estimated cost of such an arrangement is $1,820,000.

We are dubious of the effectiveness of an ice boom,

because we believe that the strength of the current is such that most of the slush ice would be forced under the boom. If the boom were to be made considerably deeper in an attempt to prevent this, the force acting on the boom would be greater and the cost would be such that some form of physical barrier would probably be as cheap. Moreover, as pointed out in the NRC report, it would be difficult to design a boom that would be certain to withstand the spring breakup, and the problems and cost of removing it annually would be very great. We do not, therefore, believe that a boom is the practical answer to the ice problem at Churchill.

Deflecting Groin

Figure B.3 shows a possible rubble mound groin which would deflect the current some distance upstream of the wharf. A long groin at a suitable angle would result in a substantial flow parallel to the groin and the momentum of this flow would tend to create a resultant flow beyond the groin away from the wharf. On the other hand the "drawing" effect of the turning basin and approach channel would still exist, and it would be difficult to estimate the exact effect of the groin without hydraulic model tests.

The NRC report express doubts about the suitability of a rubble mound groin or barrier because of the danger of large pieces of rock being picked up by the ice and dropped during the breakup in the navigation channel. Whilst it is true that boulders

in the beds of rivers are sometimes frozen into the ice and carried down considerable distances during breakup, it is probable that these are from the central portions of the river where the boulders can be completely surrounded by ice. We do not consider that there is much risk of large armour rock being picked up from a properly constructed groin by the fringes of an ice sheet.

The estimated cost of the rubble mound groin shown in Figure B.3 is $1,900,000.

The effect of a deflecting groin would be improved considerably by excavating a channel downstream. Figure B.3 shows a suggested excavation which is linked with the present turning basin. The estimated additional cost of the excavated area dredged to a depth of 27 feet is $2,700,000. It would be sensible to postpone any such excavation, however, until the effect of the groin can be judged because the deflected current may scour a deeper channel downstream and make further excavation unnecessary.

Complete Protection of Wharf and Turning Basin

Figure B.4 shows a sheet pile cell type protection of the wharf and turning basin based on the proposal in the NRC report. The estimated cost of such protection is $2,430,000. The cost would be similar if concrete or timber cribs were adopted as an alternative.

Whilst a complete enclosure of the turning basin would undoubtedly overcome the slush ice problem it has the disadvantage

of preventing further southward expansion of the harbour facilities. It might be possible to design the protective cribs so that they could be used as future berths but it would not be easy to do this unless it was known in advance for what purpose future berths might be required.

Diversion of River Above Harbour

The diversion of the river above the harbour would not only completely solve the problem of slush ice, but would also prevent the strong tidal currents at the harbour entrance which restrict the period during which vessels can enter or leave the harbour.

Any diversion above the harbour will be made easier by the diversion of the Churchill River from Southern Indian Lake into the Nelson River at present being carried out by Manitoba Hydro. This lake diversion will have the effect of greatly reducing normal flows down the river below Southern Indian Lake. The substantial storage to be provided in Southern Indian Lake will also greatly reduce the normal annual flood and significantly reduce the maximum possible flood. These effects make it possible to design a diversion immediately above the harbour more economically than would otherwise be possible.

The present intention of Manitoba Hydro is to raise Southern Indian Lake about 37 feet to a maximum storage elevation of 872. The operating range will be about 13 feet giving a live storage volume of about 10,000,000 acre feet. The storage level will

normally be drawn down during the winter months, so that a fair proportion of the live storage will be available to absorb normal spring and early summer runoff above Missi Falls Dam at the outlet from Southern Indian Lake. This means that the normal spring flood at Churchill will consist only of runoff from the unregulated catchment area below Southern Indian Lake plus a small compensation flow of about 500 c.f.s.

In occasional years of exceptional runoff, it will take several weeks for Southern Indian Lake to be filled to spillway level, so that by the time there is any significant flow over the spillway the peak of the flood from the unregulated catchment downstream will have passed.

The unregulated catchment area below Southern Indian Lake is about 14,000 square miles. The estimated mean flow from this area is about 6,200 c.f.s. and by correlation with measurements at Island Falls, the estimated maximum flood flow during the period 1929/1963 was about 20,000 c.f.s. However, there is less natural regulation below Southern Indian Lake, and it would be reasonable to allow for a normal maximum flood of about 35,000 c.f.s. This has been taken as the desirable capacity of the diversion channel above the harbour.

A preliminary consideration of recorded floods on the Churchill River and the effect on storage in Southern Indian Lake indicates that it will be most unlikely that even exceptional

floods will exceed 100,000 c.f.s. at Churchill after completion of the works by Manitoba Hydro in 1973.

To allow for flows in excess of the capacity of the diversion channel, it is proposed that the diversion causeway above the harbour should be designed so that it is capable of being over-topped by about 2 ft., under which condition it will pass a flow of about 65,000 c.f.s. Experience in recent years with the design of cofferdams on major rivers has shown that it is entirely feasible to design rock fill dams to withstand a considerable flow through or over the dam. As a result of this considerable practical experience and recent model tests, the design of permanent rock fill dams without separate spillways is now an accepted engineering technique[3].

Based on the above considerations, a typical diversion scheme is shown in Figure B.1 comprising the following:

1) A diversion causeway designed to be over-topped to the extent of about 2 ft., thus passing about 65,000 c.f.s. in the event of an unusual flood.

2) A diversion channel capable of carrying about 35,000 c.f.s. with a lake elevation of about 13 ft. above geodetic datum.

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[3] Olivier, H. "Through and Over Flow Rockfill Dams - new techniques" Proceedings - Institution of Civil Engineers, March, 1967.

3) A possible emergency spillway which could be excavated if desired to reduce the risk of over-topping the causeway. Such a channel together with an approach across it might be desirable if permanent access were required to the west side of the harbour.

The estimated cost of the diversion scheme as shown in Figure B.1 is as follows:

Diversion Causeway	$ 2,020,000
Diversion Channel	8,700,000
TOTAL	$ 10,700,000
Emergency Spillway if required	$ 2,000,000

Tidal Barrier

During the process of considering alternative schemes for diverting the river above the harbour, it became apparent that it would be possible to construct a simple tidal barrier across the estuary opposite Cockles Point without diverting the river.

The purpose of the tidal barrier would be simply to form a fresh water lake above the barrier and to cut off the estuary from the tides so that only the harbour below the barrier would be tidal.

The barrier would be so designed that the minimum fresh water flow would pass through it and normal flood flows would pass over the top without endangering its stability. The barrier would not necessarily be designed to withstand exceptional flood flows because it would probably be cheaper to repair the barrier once

every 50 years or so than to make it more elaborate in the first instance.

In common with a diversion scheme a tidal barrier would have the advantage of not only preventing slush ice from entering the harbour, but also eliminating the strong tidal currents at the harbour entrance.

It is estimated that a suitable rock fill barrier with armour protection and having a crest elevation of +9 would cost $2,900,000.

Summary

The comparative costs of the various alternative schemes discussed above are as follows:

New Channel to alter current distribution	$ 6,020,000
Ice Boom	$ 1,820,000
Deflecting Groin	$ 1,900,000
Deflecting Groin with new channel downstream	$ 4,600,000
Complete protection of wharf and turning basin with timber cribs or sheet pile caissons	$ 2,430,000
Diversion of river above harbour	$10,700,000
Tidal Barrier	$ 2,900,000

It can be seen that the cheapest schemes are the ice boom, deflecting groin protection of wharf with cribs or caissons, and the tidal barrier. Of these, we recommend the tidal barrier for the following reasons:

a) The tidal barrier would completely eliminate the slush ice whereas the other schemes only divert it downstream of the wharf, where it may still be a hazard to vessels entering and leaving the harbour.

b) The tidal barrier would also eliminate the strong tidal currents at the mouth of the harbour and increase the period during which vessels could safely enter and leave.

c) The tidal barrier would form a fresh water lake upstream of the harbour which would be available for water supply to the town site and other areas.

In view of the fact that diversion of the Churchill River by Manitoba Hydro will greatly reduce the flow entering the habour and may consequently substantially reduce the generation of slush ice, it is recommended that no substantial amounts be spent on solving the slush ice problem until the year 1973 when the diversion of the Churchill River from Southern Indian Lake is scheduled for completion. In the meantime it would be worthwhile to investigate the feasibility and cost of a tidal barrier in more detail and to assess more accurately the benefit of eliminating the strong tidal currents, irrespective of the problem of slush ice.

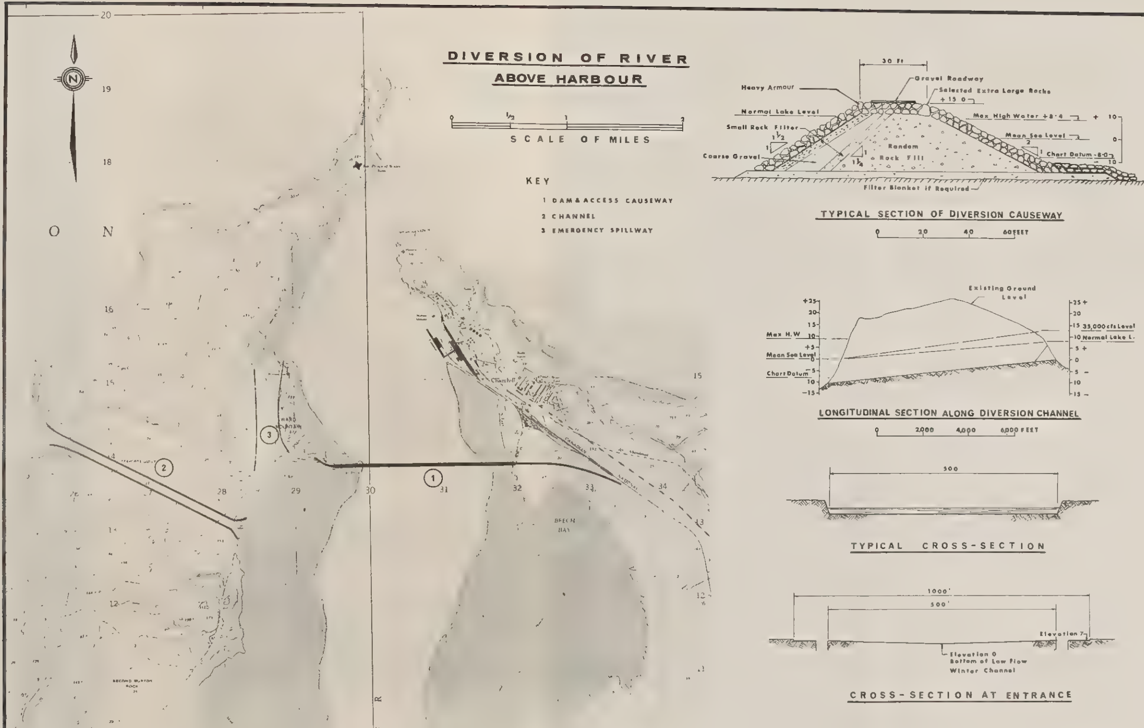
DIVERSION OF RIVER
ABOVE HARBOUR
SCALE OF MILES
KEY
1 DAM & ACCESS CAUSEWAY
2 CHANNEL
3 EMERGENCY SPILLWAY
Churchill
BEECH BAY
30 Ft
Gravel Roadway
Heavy Armour
Selected Extra Large Rocks
Normal Lake Level
Max High Water +8·4
Small Rock Filter
Mean Sea Level
Random Rock Fill
Coarse Gravel
Chart Datum -8·0
Filter Blanket if Required
TYPICAL SECTION OF DIVERSION CAUSEWAY
60 FEET
Existing Ground Level
Max H.W.
Mean Sea Level
Chart Datum
35,000 cfs Level
Normal Lake L.
LONGITUDINAL SECTION ALONG DIVERSION CHANNEL
6,000 FEET
TYPICAL CROSS-SECTION
1000'
500'
Elevation 7
Elevation 0
Bottom of Low Flow
Winter Channel
CROSS-SECTION AT ENTRANCE

FIGURE B1

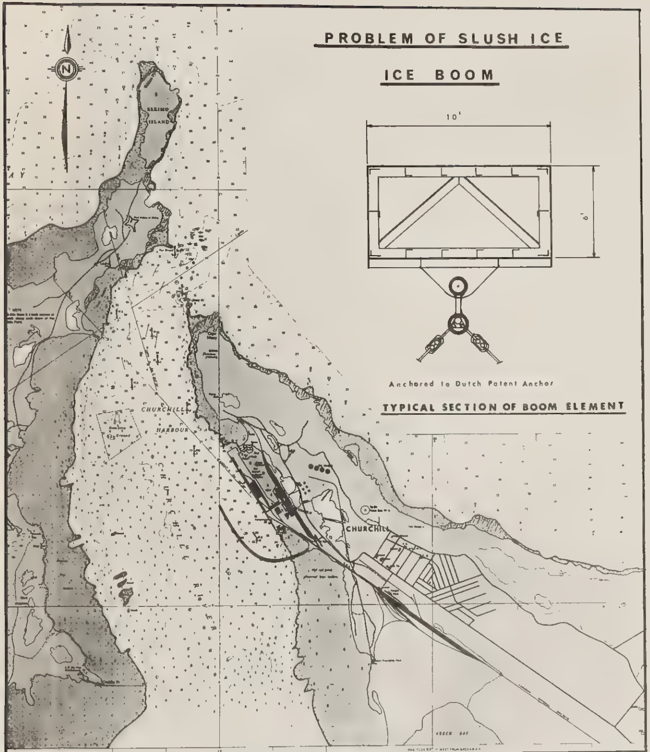
PROBLEM OF SLUSH ICE
ICE BOOM
10'
6'
Anchored to Dutch Patent Anchor
TYPICAL SECTION OF BOOM ELEMENT
N
ESKIMO
ISLAND
CHURCHILL
HARBOUR
CHURCHILL

FIGURE B 2

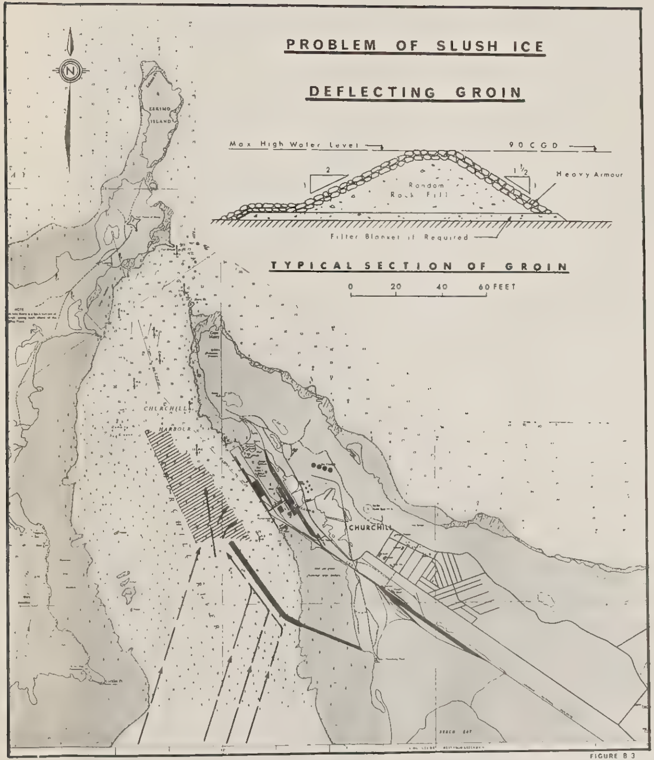
PROBLEM OF SLUSH ICE
DEFLECTING GROIN
Max High Water Level
90 CGD
2
1
1 1/2
1
Heavy Armour
Random Rock Fill
Filter Blanket if Required
TYPICAL SECTION OF GROIN
0 20 40 60 FEET
ESKIMO ISLAND
CHURCHILL HARBOUR
CHURCHILL RIVER
CHURCHILL

FIGURE B 3

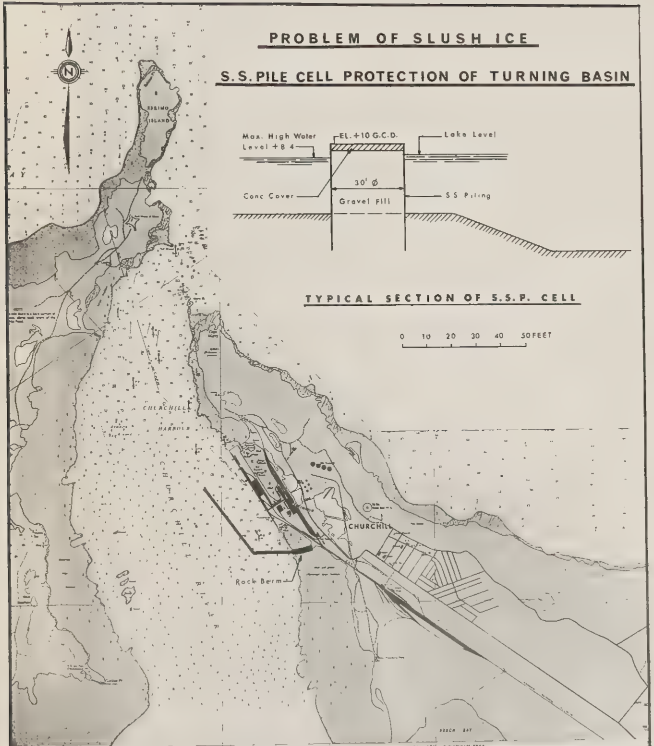
PROBLEM OF SLUSH ICE
S.S. PILE CELL PROTECTION OF TURNING BASIN
Max. High Water Level +8.4
EL. +10 G.C.D.
Lake Level
30' Ø
Conc Cover
Gravel Fill
S S Piling
TYPICAL SECTION OF S.S.P. CELL
0 10 20 30 40 50 FEET
ESKIMO ISLAND
CHURCHILL HARBOUR
CHURCHILL RIVER
CHURCHILL
Rock Berm

FIGURE B 4

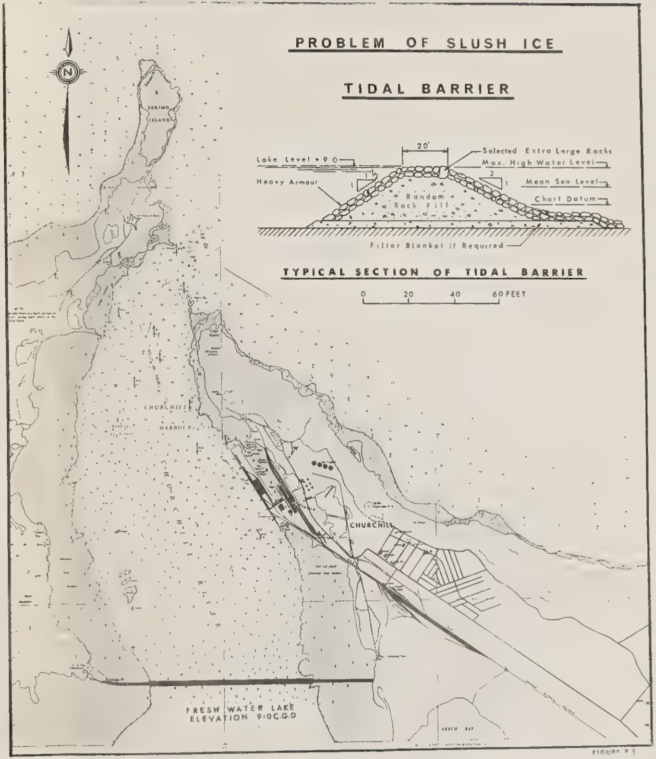
PROBLEM OF SLUSH ICE
TIDAL BARRIER
20'
Selected Extra Large Rocks
Lake Level + 9.0
Max. High Water Level
Heavy Armour
Mean Sea Level
Random Rock Fill
Chart Datum
Filter Blanket if Required
TYPICAL SECTION OF TIDAL BARRIER
0 20 40 60 FEET
ESKIMO ISLAND
CHURCHILL HARBOUR
CHURCHILL RIVER
CHURCHILL
FRESH WATER LAKE
ELEVATION 9.0 C.G.D

FIGURE P.5

APPENDIX C

GLOSSARY OF ICE TERMINOLOGY

The following provides a glossary of ice terms extracted from "Manice" by the Department of Transport, Meteorological Branch:

–	Open Water	– Less than 1/10 ice cover
–	Very open pack-ice	– 1/10 to 3/10 ice cover
–	Open pack-ice	– 4/10 to 6/10 ice cover
–	Close pack-ice	– 7/10 to 9/10 ice cover
–	Very close pack-ice	– 10/10 -- little if any water present on the sea surface (including 9+/10)
–	Transitional states:	– Belt, Patch, String
	Belt	– Long area of pack-ice from a few miles to more than 50 miles in width
	Patch	– A collection of pack-ice less than 5 miles across
	String	– Long narrow area of pack-ice about one-half mile or less in width, usually composed of small fragments detached from the main mass of ice, and run together under the influence of wind, swell or current.

Floe Size

The size of the floes varies greatly from small pieces which are less than seven feet across to great expanses of ice which exceed five miles in length.

Descriptive Term	Size Range	Guide to Size
Brash	Less than 7 feet	Pool Table Top
Ice-cake	7 feet to 30 feet	Volley Ball Court
Small Ice Floe	30 feet to 600 feet	City Block
Medium Ice Floe	600 feet to 3,000 feet	Golf Course
Big Ice Floe	300 feet to 5 miles	Small City
Vast Ice Floe	More than 5 miles	

Stage of Development

Age: The stage in the ice cycle from inception to dissolution.

New Ice - A general term which includes Frazil Crystals, Slush, Sludge, Pancake Ice and Ice Rind.

- Frazil Crystals - Fine spicules or plates of ice, suspended in water.
- Slush or Sludge - An accumulation of frazil crystals which remain separate or only slightly frozen together. It forms a thin layer and gives the sea surface a greyish or leaden-tinted colour. With light wind, no ripples appear.
- Snow Slush - Viscous mass formed as a result of a thick snow fall into cooled water.
- Pancake Ice - Pieces of newly-formed ice usually approximately circular, about 12 inches to 10 feet across, and with raised rims due to the pieces striking against each other as a result of wind and swell.

- Ice Rind - Formed by the freezing of slush on a quiet sea surface. Thickness less than 2 inches. It is early broken by wind or swell.

<u>Young Ice</u> - Newly formed level ice generally in the transition stage of development from ice-rind or pancake ice to winter ice; thickness from 2 to 6 inches.

<u>Winter Ice</u> - More or less unbroken level ice of not more than one winter's growth, originating from young ice. Thickness from 6 inches to 7 feet. Winter ice may be subdivided into medium winter-ice or thick winter-ice.

- Medium Winter-Ice - Winter ice of thickness 6 inches to 12 inches.
- Thick Winter-Ice - Winter ice more than 12 inches thick.

<u>Polar Ice</u> - Extremely heavy sea-ice, up to 10 feet or more in thickness, or more than one winter's growth. Heavily hummocked and may ultimately be reduced by weathering to a more or less even surface. Polar ice may be subdivided into Young Polar Ice and Arctic Pack.

- Young Polar Ice - Polar ice which has not melted during the first summer of its existence and which has passed over to the second phase of increase. At the end of the second winter, it attains a thickness up to 8 feet or more. It differs from ice one year old by a greater portion showing

above the surface of the water and also by the hummocks on it being smoother.

- Arctic Pack - Almost salt-free ice, having existed over two years. Thickness up from 8 feet. The ice surface is undulating. Its hummocks having melted more than once and therefore, smoothed. In cases of absence or insignificant thickness of snow cover, this ice is coloured in different tints of blue.

Surface Features

Sea ice when formed under stable conditions has a relatively smooth surface with few irregularities, but due to winds, currents and to a small extent temperature, the smooth ice is brought into motion and is broken up into floes. Continued motion causes a continuing breaking up and disfigurement to occur on the individual cake and floe, which in turn change size, thickness and concentration.

At times when extreme pressure is exerted on a large floe and fractures are caused, its topography is changed. This is known as pressure ice.

Level Ice - Ice with a flat surface, which has never been hummocked, typical with regard to bays, gulfs, straits, archipelagoes and shallow waters, where the ice formation occurs undisturbed by pressure.

Pressure Ice - A general term for ice which has been squeezed together and, in places, formed upwards. Subdivisions are Rafted, Ice Hummocked Ice and Ridged Ice.

Types of Pressure Ice

- Rafted Ice - Type of pressure ice formed by one flow overriding another.
- Hummocked Ice - Ice piled haphazardly one piece over another.
- Ridged Ice - Ridge or wall of ice where floes have been pressed against each other.
- Standing Floe - A separate floe standing vertically or inclined and enclosed by rather smooth ice.

Rafting, Ridging and Hummocking are reported in tenths according to its prevalance in a given area.

Stages of Melting

Puddle Ice - The surface of which is covered with melt water, i.e. an accumulation on the ice of water, mainly due to snow melting. The stages of development of snow water are as follows: patches of melting snow, puddles on the ice -- small and shallow accumulations of melt water on the ice, larger amounts of water, which have deepened on account of ice melting and which have sharply defined outlines.

Thaw holes in the ice - Open holes in an ice floe formed by the melting through of puddles.

Dried ice - Ice surface, from which the water has disappeared after the formation of cracks and thaw holes.

Rotten ice - Ice which has become honeycombed in the course of melting and which is in an advanced stage of disintegration.

Forms of Fast Ice

Fast Ice - Sea-ice which remains fast, generally intthe position where originally formed, and which may attain a considerable thickness. It is found along coasts, where it may be attached to the shore, or over shoals, where it may be held in position by islands, grounded ice bergs or grounded polar ice.

Bay Ice - Level ice of more than one winter's growth, which has remained unhummocked and also becomes nourished by surface layers of snow. Thickness of ice and snow up to 7.0 feet above sea level.

- IceFoot - A narrow fringe of ice attached to the coast, unmoved by tides and remaining after the fast ice has moved away.
- Anchor Ice - Ice found attached or anchored to the bottom irrespective of the nature of its formation.
- Grounded Hummock - Hummocked grounded ice formation. There are single grounded hummocks and lines (or chains) of grounded hummocks.

Openings in the Ice

Crack - Any fracture or rift in sea-ice not sufficiently wide to be described as a lead.

- Tide Crack - Crack formed between fast ice and the icefoot under the action of the fluctuations of the sea level. Typical only for fast ice areas.

Lead - A navigable passage through pack-ice.

- Shore Lead - A lead between pack-ice and the shore or between pack-ice and narrow fringe of fast ice.

Polynya - Water area enclosed in ice, generally fast. This water area remains constant and has usually an oblong form. Sometimes the polynya is limited on one side by a coast.

- Shore Polynya - Polynya along the coast, formed either by wind or current.

Pool - Any relatively small ice enclosed water area in pack-ice other than a lead.

Open Water - A relatively large area of free navigable water in an ice-encumbered sea. Less than one-tenth ice cover.

Special Terms

Ice Mosaic - Ice pieces of different ages frozen together.

Ice-Bar - Ice edge consisting of floes compacted by wind, sea and swell and difficult to penetrate.

Ice-Blink - A typical whitish glare on low clouds above an accumulation of distant ice. It is especially glowing when observed on the horizon.

Ice-Edge - The boundary at any given time between the open sea and pack-ice of any kind, whether floating or fast.

Tongue - A projection of the ice-edge up to several miles in length, caused by wind or current.

Water-Sky - Typical dark patches and strips on low clouds over a water area enclosed in ice or behind its edge. It is due sometimes

to an open water area out of the limits of visibility.

Ice of Land Origin

Types of Glacial Ice Found at Sea

- Iceberg - Large mass of floating or stranded ice, more than 16 feet above sea level, which has broken away either from a glacier or from an ice-shalf formation.
- Bergy-Bit - A medium-sized piece of ice, generally less than 16 feet above sea level and about the size of a small cottage, mainly originating from glacier-ice, but occasionally a massive piece of sea-ice or disrupted hummocked ice. When the sea-ice origin is not in doubt the term FLOEBERG may be used.
- Growler - Smaller piece of ice than a bergy-bit, frequently appearing greenish in colour and barely showing above water. May originate both from sea-ice and from glacier-ice.
- Ice island - Drifting portion which has separated off from an ice shelf.

Terms Related to Ice of Land Origin

- Glacier - A mass of snow and ice continuously moving from higher to lower ground. At the higher latitudes, they usually terminate at sea level.
- Glacier Ice - Any ice floating on the sea as a berg, which originates from a land glacier.
- Ice Shelf - Ice formation over 7.0 feet above sea level with

level surface, which originates from annual accumulations of firn-snow/neve layers on bay-ice (or the seaward extension of a glacier).

- Glacier Tongue - Projecting seaward extension of a glacier, usually afloat. In the Antarctic, glacier tongues may extend over many miles.
- Tabular Berg - A flattopped berg usually showing horizontal banding, broken off from an ice-shelf or a glacier.
- Ram/Spur - An underwater ice projection from an iceberg or a hummocked ice-floe. Its formation is usually due to a more intensive melting of the unsubmerged part of the floe.
- Calving - The breaking away of a mass of ice from its present formation. Calving may take place above or below the water line.
- Crevasse - A fissure or rift in a glacier; ice shelf, or other land ice formations, due to temperature changes or motion of the ice.

Descriptive features for various stages of development:

Stage of Development	Thickness	Rafting	Ridges	General Colour
New Ice	- 2"	Few	None - Few	Dark Grey
Young Ice	2 - 6"	Many	None - Few	Grey to Ash Grey
Medium Winter	6 - 12"	Few	Few	Ash Grey
Thick Winter	≠ 12"	None	Few - Many	Ash Grey to White
Young Polar	- 8'	None	Few - Many	Greenish Blue
Arctic Pack	≠ 8'	None	Few - Many	Bluish
Ice Shelf	≠ 20'	None	Long Rounded	Bluish
Ice Island	≠ 20'	None	Long Rounded	Bluish

APPENDIX D

THE PRAIRIE GRAIN MARKETING SYSTEM AND POTENTIAL GRAIN EXPORTS

The Port of Churchill can be considered as one part of a transportation system which has been developed to transport grain from Western Canada to offshore export markets. Production of grains in the prairie region is dependent upon domestic and, more important, export demands. In relation to the magnitude of grain exports supply is not a limiting factor. The development of prairie agriculture has in fact largely been predicated on export demands for cereal production and western farmers, to the extent possible, plan production in anticipation of future export demands.

Producer Deliveries

Once the grain is harvested some is consumed on the farm but the major portion moves into commercial channels. The western producer can move his grain into commercial positions in four different ways.

1. Deliveries to country elevators
2. Platform loadings
3. Interior terminal elevators
4. Interior private mills.

The country elevator system receives the major portion of producer deliveries. This system in Western Canada is both company owned and co-operatively owned. An individual producer is able to

deliver his grains to an elevator located a relatively short distance from the production area. The prairie country elevator system is comprised of over 5,000 country elevators located at approximately 2,000 delivery points. The storage capacity of the elevators amounts to over 375 million bushels.

The elevator companies act as agents for the Canadian Wheat Board, handling and storing grains, of which the most important is wheat. There are approximately 30 companies licensed to operate country elevators but ownership is concentrated in only a few with individual storage capacities in excess of 20 million bushels, e.g. Saskatchewan Wheat Pool, United Grain Growers Ltd., Alberta Wheat Pool, Federal Grain Ltd., Pioneer Grain Company Ltd., Manitoba Pool Elevators, National Grain Company Ltd. The above elevator companies in total operate over 90 per cent of the existing country elevators on the prairies and their aggregate capacity is well in excess of 300 million bushels. The companies annually sign "handling agreements" with the Canadian Wheat Board and receive revenue for handling and storing producer deliveries. Operating in this way as agents for the Wheat Board, the elevator companies after deducting charges for handling and storing the grains make payments to the producer on the basis of the Wheat Board authorized initial payment. The handling and storage charges are established by the Wheat Board and are set out in the "handling agreement" under which the elevator companies operate.

As can be seen in Table I in the ten-year period from 1956

to 1965 the average amount of wheat, oats, barley, rye and flaxseed delivered to country elevators was slightly under 595 million bushels annually. Deliveries to country elevators during this period accounted for over 99 per cent of the above mentioned grains placed in commercial positions. Of the grains delivered to country elevators, wheat averaged approximately 428.7 million bushels annually or just over 72 per cent of the grains mentioned. Deliveries of oats averaged approximately 48.2 million bushels annually and amounted to around 8 per cent of these grains. Country elevator receipts of barley accounted for 16 per cent of these grains, averaging approximately 94 million bushels annually. Country elevator receipts of rye during the ten-year period averaged 6.6 million bushels annually or approximately 1.1 per cent of the deliveries being considered. Flaxseed deliveries during the same period amounted to approximately 2.9 per cent of total country elevator receipts averaging 17.3 million bushels annually.

Platform loadings for that quantity of the above grains which were loaded directly onto rail cars by the producers was negligible, averaging approximately 155,000 bushels annually. During the ten-year period 1956 to 1965, wheat platform loadings were highest averaging 63,000 bushels annually, flaxseed averaging 23,000 bushels, oats averaging 21,000 and rye averaging 4,000 bushels.

The third way in which producers deliver their grains to commercial channels is through deliveries to interior public and semi-public terminals. In the ten-year period receipts at the

interior public and semi-public terminals averaged 303,000 bushels per year. Producers' deliveries to these terminals from 1956 to 1965 averaged 155,000 bushels of wheat, 104,000 bushels of oats, 43,000 bushels of barley, and 1,000 bushels of flaxseed.

Deliveries to interior private and mill elevators totalled approximately 4,982,000 bushels of wheat, oats, barley, rye and flaxseed per year during the period from 1956 to 1965. Deliveries of wheat formed the bulk of the producer deliveries to the interior private and mill elevators averaging 3,633,000 bushels per year. Deliveries of oats, barley, rye and flaxseed for this same period annually averaged 562,000 bushels, 364,000 bushels, 32,000 bushels and 391,000 bushels respectively.

In total, producer marketings in the Prairie Provinces averaged over 600 million bushels per year. The deliveries to the country elevators accounted for approximately 99.1 per cent of the total marketings, deliveries to the interior private and mill elevators were approximately 0.8 per cent of total marketings and deliveries to interior public and semi-public mills and platform loadings accounted for the remaining 0.1 per cent of total marketing. During the ten-year period wheat deliveries averaged 72.1 per cent, oats 8.1 per cent, barley 15.7 per cent, rye 1.1 per cent and flaxseed 4.0 per cent.

TABLE 1

PRAIRIE PROVINCES PRODUCER DELIVERIES
(thousand bushels)

10 Year Average 1956/1957-1965/1966	Country Elevators	Platform Loadings	Interior Public and Semi-Public Terminals	Interior Private and Mill Elevators	Total Marketings
Wheat	428,672	63	155	3,633	432,523
Oats	48,151	21	104	562	48,838
Barley	93,995	44	43	364	94,446
Rye	6,605	4	-	32	6,641
Flaxseed	17,315	23	1	391	17,730
Total	594,738	155	303	4,982	600,178

Source: Winnipeg Grain Exchange, Grain Trade Year Book.

The Forward Movement of Producers Deliveries

In so much as the country elevators receive over 99 per cent of producer deliveries, the forward movement of grain to export positions begins at the country elevators. In general, producer marketings and the transportation of the grains from the country elevators to forward terminal positions is under the direction of the Canadian Wheat Board. Delivery quotas are established by the Board for specified acreage which provides to the extent possible equal opportunities for producers to market their grain at country elevators. The elevator companies receive orders from the Wheat Board for grain from specific areas to be delivered to a certain terminal position. The elevator companies in turn transmit the Wheat Board delivery orders to elevator agents who notify railroads as to their individual

transportation requirements.

The orders issued by the Wheat Board and the allocation of box cars to country points are both based on the share of total country elevator receipts delivered to individual companies at specific country stations. The activity of the railroads in transporting wheat destined for export from country elevators to forward terminal positions is directed, in a general way, by the Board. Early in the crop year the railroad is informed by the Board of what to expect regarding the volume of grain which they will be directed to transport to various terminals. The railroad in anticipation of orders for cars from elevator agents can plan for the equitable distribution of available cars among the numerous country delivery points. The allocation of available cars to individual elevators is made on the basis of current deliveries received by each. The bulk of wheat destined for export is shipped by rail to forward terminal elevators located on the West coast, Churchill and the Lakehead -- very little is railshipped to the lower lakes, St. Lawrence and the Maritimes.

Forward Terminal Positions

The railways transport grains destined for export from country elevators to terminal elevators where the grains are officially graded by the Board of Grain Commissioners Inspection Branch. The terminal elevators in effect form staging areas for grain which is to be exported. There are a few inland terminal elevators, but the majority are located either at salt water ports or the fresh water

ports on the Great Lakes and St. Lawrence River. The ownership of the terminal elevators is divided between the Canadian Government terminals operated by the Board of Grain Commissioners, terminal elevators operated by the National Harbours Board and those owned and operated by elevator companies. At these terminals grain receives final grading by the Board of Grain Commissioners and is then tran-shipped for export destinations.

The major terminal areas in Canada from which grain is exported are the Pacific West Coast, the Maritime ports, the St. Lawrence, Churchill and the Great Lakes. Grain is transhipped direct from the Pacific West Coast, Churchill, the Maritime ports and to a large extent from lower St. Lawrence ports, but the bulk of grain loaded on vessels at terminal elevators situated at ports on the Upper Great Lakes is transhipped to terminal elevators at ports on the Upper St. Lawrence, Lower St. Lawrence and Maritime ports. At the fore-going ports the grain is transferred to terminal elevators. Depending upon export market demands, the grain is then held in storage or loaded on ocean vessels and transported to export destinations in Western Europe, Eastern Europe, Asia, Africa and the Western Hemisphere.

Potential Markets for Wheat Exports

The projected volumes of wheat which might potentially move through the Port of Churchill are largely based upon assumptions concerning future external factors of supply and demand for wheat and the way in which these external factors will affect domestic production. The

production of grains in Western Canada are predicated on both domestic and export demands with the export demands exerting the greatest influence. Therefore before potential wheat exports which might move through the Port of Churchill can be arrived at it is first necessary to consider future wheat export demands and the offshore areas which will exert this demand.

In the future it is expected that Western Europe and the United Kingdom will continue to demand large quantities of both wheat and other grains. Production of feed grains and wheat for human consumption has increased dramatically in Western Europe during the 1950's and the first half of the present decade, consumption has increased even more. The land available for grain production is under considerable pressure to produce both feed grain requirements and large quantities of grain for human consumption. It would seem quite unlikely that wheat production in this region could satisfy consumption requirements in the period up to 1985.

Western Europe and the United Kingdom imports large quantities of wheat. In the past millers in this market area have relied heavily upon wheat imports for milling. Domestic wheat lacked properties desired by millers and very large quantities of wheat imports of high quality hard wheat were used in the milling process. The traditional market for Canadian wheat has been in supplying a large portion of the Western European milling requirements. In recent years, milling techniques have been improved and millers in Western Europe are now able to use larger amounts of European wheat and require smaller amounts

of imported wheat to supplement their milling needs. Despite these new milling techniques it is expected that millers will continue to import significant quantities of high quality hard wheat. Though the total wheat imports of these countries may decline, it is expected that future imports from Canada will continue to be made in substantial quantities.

In the last decade and a half the U.S.S.R. and other Eastern European countries have relied upon their own production to supply domestic needs. Periodically when crops were poor these countries have made demands on the wheat export market in order to supplement domestic deficit production. Available land in Eastern Europe is subject to much the same pressures as is available land in Western Europe. The U.S.S.R. is increasing consumption of red meats and in so doing increases pressure on available land through the resulting increased requirements for feed grains. In view of expected continued demands for increased volumes of food wheat and at the same time increased red meat consumption, Eastern Europe in the future will most likely go to the export market to supplement domestic grain supplies. It is very difficult to forecast the future demand for wheat by centrally planned countries with any degree of confidence, but because of the vagaries of weather and the possibility of continued and increased pressures on available land, it is assumed that Eastern Europe will continue to import significant quantities of wheat.

It is expected that both concessional and commercial import wheat demands in Asia will continue to increase. In spite of repeated

statements to the contrary it is expected that India will continue to import substantial quantities of wheat to supplement domestic production. Distribution problems and periodic calamitous droughts, floods and plant and insect infestations will continue to keep India in a chronic wheat deficit position. Japan is a developed country and has developed an appetite for high quality wheat for milling purposes. Competition for available land by alternate types of agricultural production within Japan will contribute to increasing demands for wheat imports.

As in the case of centrally planned countries of Eastern Europe, it is very difficult to forecast the import demands of Red China. In the recent past, the China mainland has periodically imported large quantities of cereal grains for human consumption. It is expected that population will continue to exert pressures on available land. As in the past, it is expected that in the future, adverse conditions will create periodic deficits of food supplies. It is therefore expected that China periodically will demand substantial quantities of wheat imports.

Africa will demand cereal grains both to offset production deficits and for milling requirements. The African continent contains both high and low income countries. Though some countries in Africa are endowed with rich land resources, others are poor in terms of land resources. At the present time only a few areas within Africa are able to produce surplus supplies of grain. It is not expected that the more developed high income African countries will demand a high quality wheat for milling purposes while less developed low income

countries will demand food grains to offset domestic deficits in order to meet nutritional requirements. It is quite likely that a wheat market will emerge in areas where corn or beans are now the main element in the human diet. It is in this shift that new wheat markets will be created.

As in the case of Africa, the Western Hemisphere (excluding United States) contains both high and low income countries, many of which are poor in nutritional resources and with a limited capacity to produce surplus food supplies. Argentina is a major exporter of grains. But because of limitations of land resources and future domestic requirements it is not expected that Argentina will be able to contribute significantly to future increased demands on the export market. Less developed areas in the Western Hemisphere now rely on corn or beans as the main element in the human diet as in the case of some areas of Africa. It is quite likely that a wheat market will develop in these areas through a shift from a corn and bean diet to a wheat diet because of the greater nutritional benefits which can be derived from a wheat diet.

Prospects for Canadian Wheat

It is expected that by 1985 the effective world trade in wheat will be in the area of 3 billion bushels. Potential areas for Canadian grain sales will be Western Europe, Eastern Europe, Asia, Africa and the Western Hemisphere (including United States). The success of Canada's future wheat trade will largely depend upon

Canada's ability to produce reasonably priced wheat and to a large extent in the promotion and selling activity which will be directed towards what could very likely be a highly competitive market. The United States is now the largest exporter of wheat. If Canada is to achieve any measure of success in future wheat exports Canada will have to compete effectively with the United States for a growing wheat export market.

Future Production - Wheat

The magnitude of future wheat production in Canada will to a large part depend upon future world demands. It is expected that by 1985 the world export wheat market will be approximately 3 billion bushels. A range of production possibilities face future prairie wheat producers. If export demands for wheat continue to reflect a desire for high quality hard wheat possibly 30 million acres might be allocated to producing high quality wheat. If, on the other hand, quality was to become increasingly less important and price more important acreage would decline and yields increase at the expense of quality. Two models have been developed to establish parameters for a projected range of production possibilities. Model A assumes that high quality will remain important in production while Model B assumes that quality will become secondary and yields will be of prime importance.

TABLE 2

WESTERN CANADIAN WHEAT
PROJECTED ACREAGE, YIELD AND PRODUCTION
MODEL A AND MODEL B

	Acres (million)		Yield (bushels/acre)		Production (million bushels)	
	A	B	A	B	A	B
1970	30.0	26.0	23.4	23.5	702.0	610.0
1975	30.0	25.0	24.6	24.8	738.0	620.0
1980	30.0	24.0	25.8	26.8	774.0	680.0
1985	30.0	23.0	27.1	28.8	813.0	660.0

Source: Hedlin, Menzies & Associates Ltd.

Projected Exports to 1985

Depending upon the market conditions which exist and the competitiveness of Canadian grains in future export markets, the prospects for specific grain exports could be either favourable or unfavourable. The present trend in wheat exports indicate that if the recent trend continues the prospects for future wheat exports will not be overly optimistic.

TABLE 3

CANADIAN WHEAT EXPORTS

	Million bushels
1960-1961	308
1961-1962	323
1962-1963	200
1963-1964	537
1964-1965	367
1965-1966	546
1966-1967	483
1967-1968	311

Source: Dominion Bureau of Statistics.

Since 1965-1966 exports of wheat have declined each year while surpluses have remained high. Decreasing sales rather than insufficient supplies have caused these declines. A number of factors have compounded to reduce the export sales of Canadian wheat in recent years.[1]

1. The world harvested a relatively large wheat crop in 1967, following a large crop in 1966 and so increased total stocks of wheat.

2. The market areas that have historically bought large volumes from Canada had particularly large crops in 1967. Western Europe produced some 200 million bushels more wheat in 1967 than in 1966 and there was a corresponding increase in production in the Communist Bloc in Eastern Europe.

3. The United States harvested a large crop in 1967 and, partly as a consequence of this and partly as a consequence of a balance of payments problem, has enunciated the objective of moving 750 million bushels of wheat to market in the current crop year (actual exports of wheat and flour exceeded 750 million bushels). This stated objective of the United States implies the securing for that country of almost half of the total market that will be available to the traditional exporting countries during the crop year. As a consequence competition for wheat markets has been greatly intensified.

4. A larger than usual percentage of world trade will be supplied in the current crop year (1967-1968) by suppliers that are not traditional exporters -- countries such as France, Spain, Sweden, Bulgaria, Romania and Iran. This will be at the expense of the principal exporting countries -- the United States, Canada, Australia and Argentina.

5. In the current crop year the International Wheat Agreement is not operative and maximum and minimum prices for wheat are not defined for 1967-1968 (International Grains Agreement operative as of June, 1968). The usual concensus, as a consequence, is lacking and asking prices for wheat are below the minimum price for wheat that was provided in the International Wheat Agreement that lapsed on June 30, 1967.

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[1] Hedlin, Menzies & Associates Ltd., Canadian Wheat: Problems and Prospects, 1968.

Added to the above factors has been the practice of millers in Canada's traditional Western European markets in recent years to use decreasing amounts of Canadian wheat for milling. Milling techniques have improved and millers are now able to use greater quantities of their softer domestic varieties thus to some extent reducing their demands for high quality Canadian hard spring wheat.

Prospects for new markets appear good. As the income of developing countries rise, it is quite probable that their consumption patterns will change to include greater amounts of milling products resulting in new demands for Canadian wheat. The main diet of many countries in Africa, Central America and South America is primarily maize and beans. A diet centered mainly on maize is relatively low in nutritional value. Perhaps these countries will in the future concentrate on raising the nutritional value of their diets. If this does occur high protein wheats might be selected as a substitute food thus improving prospects for future wheat exports from Canada.

Potential Markets For Feed Grains and Oilseeds

Potential offshore exports of feed grains and oilseeds from the Churchill Hinterland, as with wheat, depend upon future production, domestic consumption, future export market demands and the competitiveness of Canadian grains in the export markets. In order to develop the potential of the Hinterland for exporting feed grains and oilseeds a number of assumptions were made in regard to both future export markets and production on the prairies. The major determinant of potential export traffic in feed grains and oilseeds through the Port of Churchill is the size and location of future offshore markets.

In the post war era meat consumption in the United Kingdom and western Europe has increased tremendously. This increased meat consumption has demanded ever increasing feed grain inputs adding to the considerable pressures on available agricultural land. Increasing feed grain consumption is expected to continue through 1985. Though Western Europe has been able to substantially increase domestic production of feed grains a deficit in domestic supply remains. Increasing imports of feed grains have been required to supplement domestic production and it is expected that even larger volumes of feed grain imports will be required to 1985.

Oilseeds are now imported by the United Kingdom and Western Europe but the quantities in comparison to wheat and feed grains are rather small. It is expected that Western Europe will continue to import oilseeds for both human consumption and industrial consumption.

To date, the U.S.S.R. and other Eastern European countries have relied mainly on their own production for feed grain supplies. Per capita consumption of red meats in the U.S.S.R. is now only about 40 per cent of what it is in the United States. If the U.S.S.R. is to achieve any measure of success in long term production goals, livestock production must be increased significantly. Because of the present demands on available land for wheat production, it is assumed that increases in livestock production will to a large extent be predicated upon imported feed grains. With the possibility of continued competition for alternate land uses, it is assumed that Eastern Europe will continue to import significant quantities of wheat and it is also

likely that a demand will develop for feed grain imports.

Present trends indicate that the consumption of imported feed grains and oilseeds will continue in Asia through 1985. Meat consumption is increasing in Japan resulting in an increasing need for feed grains. Japan is also a major consumer of oilseeds. It is expected that the amount of oilseeds consumed and imported by Japan will steadily increase throughout the projection period. Significant quantities of barley and oilseeds will probably be imported by other Asian countries. The import of barley for human consumption rather than as a feed grain may become quite substantial in the projection period.

Prospects for Canadian Feed Grains and Oilseeds

The estimated size of effective demand for feed grains in 1985 is 2.5 billion bushels. Potential areas for future export sales of Canadian feed grains are the United Kingdom, Western Europe, Eastern Europe and Asia. In order to capture new markets and increase exports to historical markets Canada must produce a reasonably priced feed grain which can compete effectively with United States feed grains.

It is expected that Canada will be able to produce a reasonably priced feed grain through crop specialization and the increased application of management techniques and fertilizer to increase yields and reduce production costs. Production of a reasonably priced feed grain alone will not be sufficient to substantially increase exports. Sales activity abroad, as with wheat must become more intense if Canada

is to effectively compete for existing and new feed grain markets. Existing markets for Canadian oilseed are expected to steadily increase their oilseed demands for both human and industrial consumption.

Future Production - Feed Grains and Oilseeds

During the 10 year period from 1956-1957 to 1965-1966, acreage allocated to feed grain production (barley and oats) averaged approximately 12.5 million acres. In the same period production of oats averaged 228 million bushels annually and barley averaged 196 million bushels annually. Well over 50 per cent of this production was consumed on local farms. Because of its low density commercial distribution of oats is restricted due to high transportation costs. Barley, on the other hand, is a heavier grain and better able to bear transportation costs and is commercially distributed in significant quantities. It is expected that production of oats will largely be consumed on the farm but that barley will to an increasing extent be distributed commercially both offshore and domestically.

There is a growing beef industry in the prairie region. This industry now demands and will continue to demand a reasonably priced feed grain. If barley produced on the prairies is to meet these growing needs, adjustments will be required. Price must be lowered through increasing yields.

If adjustments were not to occur in barley production, yields will probably remain around 30 bushels per acre throughout the projection period (1970 tc 1985) and land allocated to barley production will probably be limited to 10 million acres. Average annual production

would then be in the area of 300 million bushels.

If, on the other hand, barley production on the prairies were to undergo adjustments to meet increasing domestic and foreign demands for feed grains, rural acreage allocated to barley production could quite probably reach 12 million acres with average yields in the area of 50 bushels per acre. If the latter set of conditions were to be realized, barley production would have to become more specialized. Rather than as one product of a mixed farm output, farm units would have to specialize in barley production in order to reach a scale of operation which would allow a much greater use of fertilizers.

The foregoing discussion has only dealt with barley and oats as future feed grains. It is quite conceivable that some other type of grain could possibly be produced on the prairies to supply both the domestic feed grain needs and for the export market. At present there are a variety of high yield grains under development such as Mexican Dwarf wheat, triticale and others. If the development of any one of these grains proved successful and it was widely accepted on the prairies as a feed grain, it could very likely replace barley as the major commercial feed grain.

Within the scope of this study, discussion on feed grain production is limited to the two sets of conditions relative to the production of barley, Model A and Model B. In the following table, Model A assumes that barley production will continue much the same as it has in the past. Model B assumes that adjustments will take place in barley production and that acreage and yields will both increase

substantially.

TABLE 1

WESTERN CANADIAN BARLEY
PROJECTED ACREAGE, YIELD AND PRODUCTION
MODEL A AND MODEL B

	Acres (million)		Yield (bushels/acre)		Production (million bushels)	
	A	B	A	B	A	B
1970	10.0	10.0	30.0	35.0	300.0	350.0
1975	10.0	12.0	30.0	45.0	300.0	540.0
1980	10.0	12.0	30.0	50.0	300.0	600.0
1985	10.0	12.0	30.0	50.0	300.0	600.0

Source: Hedlin, Menzies & Associates Ltd.

Oilseed production in Western Canada will be mainly rapeseed and flaxseed. It is expected that flaxseed will continue to steadily increase in production and that there will be significant increases in rapeseed production. In the base period acreage in flaxseed was slightly over 2 million acres with production at approximately 20 million bushels per year. Rapeseed is a relatively new crop to the prairie region. During the base period acreage in rapeseed was approximately 753 thousand acres and production averaging 10 million bushels per year. Production of flaxseed during the projection period it is estimated will reach just over 23 million bushels with acreage remaining slightly over 2 million. Acreage in rapeseed on the other hand is expected to increase substantially and that by 1985 production will average between 35 and 40 million bushels per year.

Projected Exports to 1985

As in the case of wheat, two projections have been made for feed grains with each projection incorporating a different set of assumptions. The first projection or Model A views prospects for future feed grain exports as favourable, the second projection or Model B views prospects for future feed grain exports in a less favourable light.

At the present time Canada does not actively compete in the export of feed grains. Feed grain exports from Canada are declining in relative terms while world feed grain exports are increasing sharply.

TABLE 2

CANADIAN OVERSEAS EXPORTS OF FEED GRAINS
(million bushels)

	Barley[a]	Oats	Total
1960/61	29.5	1.1	30.6
1961/62	26.9	1.7	28.6
1962/63	8.3	18.1	26.4
1963/64	32.9	16.0	48.9
1964/65	25.0	12.2	37.2
1965/66	29.0	14.1	43.1
1966/67	45.7	2.4	48.1

Source: Annual Report of the Canadian Wheat Board, 1966-67.

[a]Includes malting barley.

If Canada does not choose to compete for a larger share of the growing world export market for feed grains, feed grain exports can at best be expected to remain static and Canada's position relative

to world exports of feed grains will continue to decline. The major portion of the increased demands for feed grain exports in this decade have been met by reasonably priced United States corn and sorghums. Therefore, if Canada is to compete successfully for this growing market attention must be given to producing feed grains which are not priced far above United States feed grain exports.

A number of high yield grains are now in the development stage which may in the future prove to be suitable for production in the prairie region. Barley at present is the major feed grain exported overseas from the prairie region. Evidence, based on the experience in some areas of Manitoba of yields in excess of 60 bushels per acre indicate that with proper management and use of herbicides and fertilizers barley can be produced at a reasonable cost. If production of this type were to expand, sufficient volumes of barley could be produced both to supply domestic demands and to substantially increase overseas exports. Perhaps increases in feed grains might be realized with one of the high yield grains now being developed but for the purpose of projecting exports barley has been treated as the only major feed grain which Canada will export during the projection period.

Model A projects barley exports assuming that under proper management and application of fertilizers and herbicides, yields can be increased substantially thus reducing the cost and subsequently price. Priced reasonably and produced in sufficient quantity, overseas exports of barley could well be expected to increase substantially. Model A assumes that the conditions will be met in the projection period

to allow Canada to effectively compete for a larger share of the feed grain export market.

Model B assumes that barley will not be produced at a cost which will allow Canadian barley to effectively compete for feed grain export markets with United States feed grains. Model B projects barley exports to decline to a level of 30 million bushels annually by 1970 and remain at this level throughout the projection period.

TABLE 3

PROJECTED OVERSEAS EXPORTS OF CANADIAN FEED GRAINS
(million bushels)

	Model A	Model B
1970	75	30
1975	100	30
1980	125	30
1985	150	30

Source: Hedlin, Menzies & Associates Ltd.

Rapeseed export trends to Europe, because of supplies which will become available and if present efforts to market in this area remain unchanged, are expected to decline slightly during the projection period. Trends in Asia, on the other hand, indicate that this market will appreciably expand during the projection period. Therefore, both Models A and B project steady increases from 1970 through 1985 since future increases in Asia are estimated to more than offset the expected decrease in Europe.

Flaxseed export trends in Europe indicate the demand will decrease slightly, but as in the case of rapeseed, trends indicate that flaxseed exports to Asia will increase in sufficient amounts so as to offset any decrease in Europe. Both Models A and B project total flaxseed exports to increase steadily from 1970 through 1985.

APPENDIX E

INSURANCE ON VESSELS USING THE PORT OF CHURCHILL

The cost of insurance on ocean-going vessels consists of the premium for basic insurance plus any additional premium for routes representing additional hazards, such as the Hudson Bay route, the Great Lakes and the St. Lawrence Seaway, and the St. Lawrence River and Gulf during the winter months. The premium for basic insurance varies widely depending on the record of the fleet, the type and age of vessel, the ratio of the insured value to replacement value and the state of the charter market. Basic insurance does not affect the competitive position of one route relative to another and what matters, in the case of the Hudson Bay route, is the additional premium if this is a significant proportion of the overall freight cost.

In the early years after the Port of Churchill was opened, the minimum additional premium for the Hudson Bay route was very high because the hazards involved were uncertain. As operational experience accumulated, the premium for vessels fitted with gyro compass has been very substantially reduced as shown in Table 1. The minimum additional premium fixed on July 4, 1956, still applies except that 10 per cent has been added to the rate per Gross Registered Ton to allow for devaluation of the pound sterling in November 1967. The minimum additional premium is for insurance known in the trade as "With Average and Free of Particular Average

TABLE 1

HUDSON BAY
MINIMUM ADDITIONAL PREMIUMS

Date	Per Ton G.R.T.				Percentage on Insured Value			
	With Gyro		Without Gyro		With Gyro per cent		Without Gyro per cent	
	s.	d.	s.	d.	s.	d.	s.	d.
12th March, 1931	2	0	2	0	50	0	50	0
12th May, 1932	2	0	2	0	40	0	50	0
13th March, 1935	1	6	1	6	22	6	30	0
30th April, 1936	1	6	1	6	17	6	30	0
10th May, 1937	1	6	1	6	15	0	30	0
1st August, 1940	All additional premiums subject to a 25 per cent increase on the 1937 rates.							
15th January, 1941	All additional premiums subject to a $37\frac{1}{2}$ per cent increase on the 1937 rates.							
16th March, 1942	2	3	2	3	22	6	45	0
1st July, 1947	2	0	2	0	20	3	40	6
15th March, 1949	1	6	2	0	15	0	40	0
1st May, 1950	1	0	2	0	10	0	40	0
9th June, 1952		9	2	0	7	6	40	0
4th May, 1953		9	2	0	6	8	40	0
4th July, 1956	1	0	2	0	5	6	40	0

Source: Twenty-first Report on Hudson Bay Marine Insurance Rates - 1962 (Commonwealth Shipping Committee).

Unless". It applies to vessels not over 15 years old that do not pass Cape Chidley before July 23 and leave Churchill on or before October 15.

The current minimum additional premium for the Hudson Bay route is shown in the attached schedule and, in terms of Canadian currency, is as follows:

Per Ton on G.R.T.	- 14.3¢
Percentage on Insured Value	- 27.5¢ per $100

What this amounts to in terms of cents per bushel of grain depends on the size of the vessel and its insured value. For new vessels it is estimated that it would be about 2.0 cents per bushel for a vessel with a capacity of 15,000 tons dwt., and 1.5 cents per bushel for a vessel with a capacity of 50,000 tons dwt.

During the summer season when the Hudson Bay route is open, there is no additional premium for vessels proceeding to ports in the St. Lawrence River and Gulf. During the winter months vessels proceeding to the latter ports pay a minimum additional premium as shown in the attached schedule plus 10 per cent addition to the G.R.T. rate. In terms of Canadian currency the highest of these premiums for unstrengthened vessels proceeding west of Baie Comeau to, say, Quebec, Three Rivers or Montreal during the period January 1 to March 31 is as follows:

Per ton on G.R.T.	- 53.6¢
Plus Percentage on Insured Value	- 18.75¢ per $100

For new vessels it is estimated that this would amount to about 2.3 cents per bushel for vessels of 15,000 tons dwt. and about 1.8 cents per bushel for vessels of 50,000 tons dwt. It may be said, therefore, that the minimum additional premium for the Hudson Bay route is, in effect, slightly lower than the minimum additional premium for full winter operation in the upper Lawrence.

During a visit to England a meeting was held with five members of the Warrantees Sub-Committee of the Joint Hull Committee at which the insurance of vessels using the Hudson Bay route was discussed in relation to possible extension of the shipping season. The main impressions obtained from the discussion were as follows:

1. The Joint Hull Committee would be receptive to the suggestion of extending insurance coverage to a later date once the slush ice problem had been solved and the latest facts regarding ice conditions were available to them.

2. The Committee would be prepared to consider the insurance of ice-strengthened vessels beyond the normal season when the time comes that this should be required.

3. The Committee seemed willing to cooperate in bringing about any justifiable changes in hull insurance provided that adequate information was available to them.

CHURCHILL

MINIMUM ADDITIONAL PREMIUMS FOR ONE DIRECT IN AND OUT VOYAGE.

Warranted vessels properly fitted with and equipped for the use of wireless direction finding apparatus.

The rates set out in this scale are minimum rates applying to vessels not over 15 years old. Vessels over 15 years of age to be rated at the scale rates plus an additional according to age with a minimum of 25% but approved vessels over 15 years of age may be accepted at the scale rates without additional.

Warranted that vessels do not pass Cape Chidley before the 23rd July, or held covered as below*

Vessels intending to proceed into Hudson Strait before the 10th August must, immediately before sailing west of Cape Chidley, request the Ice Information officer at Churchill or the Canadian Government patrol ship to supply information regarding weather and ice on the proposed route and must take into account any recommendations received in replies. Vessels are not to proceed if any reply advises that it is unsafe to do so.

Warranted that vessels leave Churchill on or before the 15th October. For extensions up to the 20th October the rates are to be increased by 25%.

	Hulls Insured W.A. and F.P.A. Unless			Hulls Insured F.O.D. and F.P.A. Absolutely			Interests Insured T.L.O.
	Per Ton on G.R.T.	plus	Percentage on Insured Value	Per Ton on G.R.T.	plus	Percentage on Insured Value	Percentage on Insured Value
Vessels fitted with gyro compass . . Warranted vessels properly fitted with gyro compass. Gyro compass to be inspected by the makers or their agents immediately prior to the vessel leaving for Churchill	1/-d.		5/6d.%	6d.		5/6d.%	5/6d.%
Vessels not so fitted . .	2/-d.		40/-d.%	1/-d.		40/-d.%	40/-d.%

*For each day prior to the 23rd July vessel to pay in addition 100% of the Scale A.P.

Continued . . .

Overlapping Policies. - Where policies expire during a period for which an A.P. is payable, thereby causing overlapping, Underwriters shall make fair and reasonable arrangements in the event of additional premiums becoming due on two sets of policies.

Freight. - The A.P. payable on Freight is to be the T.L.O. rate plus the rate per cent, produced by the tonnage A.P. on the full insured value of the H. & M. calculated as if the vessel were insured on F.P.A. absolutely conditions.

Dual Valuation. - (Hulls Only). - In cases of dual valuation, the "Percentage on Insured Value" is to be applied to the value insured against Total Loss.

Excess Conditions. - No reduction to be made in the rates except that where the policy conditions contain a deductible franchise of 20/-per G.R.T. or over (minimum Ŀ1,500) or of Ŀ7,500 or over individual cases may be submitted to the Joint Hull Committee for consideration.

Cumulative Additional Premiums. - When a voyage involves two or more scales reference should be made to the Appendix on cumulative additional premiums.

BREACHES OF INSTITUTE WARRANTIES

Applicable to scales dated earlier than 18th November, 1967.

For all vessels, the additional premium per ton on G.R.T. and all deductibles, referred to in the scales, are to be increased by 10% (Amounts, expressed as percentages on insured value are unchanged.)

Source: Warrantees Sub-Committee of the Joint Hull Committee.

NORTH AMERICA (ATLANTIC)

MINIMUM ADDITIONAL PREVIUMS FOR CANCELLING No. 1 (a) (ii) AND (iii) OF THE INSTITUTE WARRANTIES.

Warranted vessels properly fitted with and equipped for the use of wireless direction finding apparatus, radar, gyro compass and echo sounding device.

The rates set out in this scale are minimum rates applying to vessels not over 15 years old. Vessels over 15 years of age to be rated at the scale rates plus an additional according to age with a minimum of 25% but approved vessels over 15 years of age may be accepted at the scale rates without additional.

Vessels intending to navigate in the Gulf of St. Lawrence between 15th December and 30th April b.d.i. must, at least 36 hours before entering the Gulf, request the Ice Information Officer at Sydney, N.S. or where appropriate the District Marine Agent at Quebec to supply information regarding weather and ice on the proposed route and must take into account any recommendations received in replies. Vessels are not to proceed if any reply advises that it is unsafe to do so. Vessels engaged in continuous local trading are to maintain close contact with the navigational authorities in the area and be guided by their recommendations.

Continued . . .

Each In and Out Voyage or v.v.	Periods (b.d.i.)	Hulls Insured W.A. & F.P.A. Unless		Hulls Insured F.O.D. & F.P.A. Abs.		Ints. Insured T.L.O.
		Per Ton on G.R.T. plus	Percentage on Insured Value	Per Ton on G.R.T. plus	Percentage on Insured Value	Percentage on Insured Value
Area I(a)(ii) South of $52^{o}10'$N. Lat. in the area bounded by lines drawn between Battle Harbour/Pistolet Bay; Cape Ray/Cape North; Port Hawkesbury/Port Mulgrave and Baie Comeau/Matane.	1st Dec.-15th Dec. & 16th Apl.-30th Apl.	7½d.	1/3d.%	4d.	1/3d.%	1/3d.%
	16th Dec.-31st Dec. & 1st Apl.-15th Apl.	1/3d.	2/6d.%	7½d.	2/6d.%	2/6d.%
	1st Jan.-31 Mar.	2/6d.	3/9d.%	1/3d.	3/9d.%	3/9d.%
Area I(a)(iii) West of Baie Comeau/Matane (but not west of Montreal)	16th Nov.-30th Nov. & 1st May-15th May	7½d.	1/3d.%	4d.	1/3d.%	1/3d.%
	1st Dec.-15th Dec. & 16th Apl.-30th Apl.	1/3d.	2/6d.%	7½d.	2/6d.%	2/6d.%
	16th Dec.-31st Dec. & 1st Apl.-15th Apl.	2/6d.	3/9d.%	1/3d.	3/9d.%	3/9d.%
	1st Jan.-31st Mar.	3/9d.	3/9d.%	1/10½d.	3/9d.%	3/9d.%

OVERLAPPING AREAS AND/OR PERIODS. If an inward or outward passage overlaps two or more areas or periods, the highest area rate and/or period rate shall be charged. If an inward passage is made in one period and an outward passage in another or vice versa the rate to be charged is 50% of the in-and-out voyage rate for each period concerned.

Continued . . .

SEASON CANCELLATION						
Excluding Continuous Local Trading						
Area I(a)(ii) ..	1st Dec.-30th Apl.	5/-d.	7/6d.%	2/6d.	7/6d.%	7/6d.%
Areas I(a) (ii) and (iii)	16th Nov.-15th May	7/6d.	11/3d.%	3/9d.	11/3d.%	11/3d.%
Continuous Local Trading						
Area I(a)(ii) ..	1st Dec.-30th Apl.	10/-d.	15/-d.%	5/-d.	15/-d.%	15/-d.%
Areas I(a) (ii) and (iii)	16th Nov.-15th May	15/-d.	22/6d.%	7/6d.	22/6d.%	22/6d.%

Short Periods of Continuous Local Trading

The appropriate scale additional premium for one in-and-out ocean voyage is to be applied for each 15 days or part thereof. Where there is also an inward or outward ocean passage, the appropriate rate for the passage is also to be paid.

For vessels possessing Lloyd's Register Ice Class, the additional premium may be reduced by:-

Ice Class 1. 50%

Ice Class 2. 25%

Ice Class 3. 12½% - also applicable to vessels annotated in Lloyd's Register "Str.nav.ice".

The Joint Hull Committee will give consideration to equivalent standards of other Classification Societies.

Continued . . .

Overlapping Policies. - Where policies expire during a period for which an A.P. is payable, thereby causing overlapping, Underwriters shall make fair and reasonable arrangements in the event of additional premiums becoming due on two sets of policies.

Freight. - The A.P. payable on Freight is to be the T.L.O. rate plus the rate per cent, produced by the tonnage A.P. on the full insured value of the H. & M. calculated as if the vessel were insured on F.P.A. absolutely conditions.

Dual Valuation. - (Hulls only). - In cases of dual valuation, the "Percentage on Insured Value" is to be applied to the value insured against Total Loss.

Excess Conditions. - No reduction to be made in the rates except that where the policy conditions contain a deductible franchise of 20/- per G.R.T. or over (minimum £1,500) or £7,500 or over individual cases may be submitted to the Joint Hull Committee for consideration.

BREACHES OF INSTITUTE WARRANTIES

Applicable to scales dated earlier than 18th November, 1967.

For all vessels, the additional premium per ton on G.R.T. and all deductibles, referred to in the scales, are to be increased by 10% (Amounts, expressed as precentages on insured value are unchanged.)

Source: Warrantees Sub-Committee of the Joint Hull Committee.

APPENDIX F

STATEMENT ON THE NATIONAL OIL POLICY
BY
THE HONOURABLE GEORGE HEES
MINISTER OF TRADE AND COMMERCE
IN
THE HOUSE OF COMMONS
FEBRUARY 1, 1961

As the House is aware, the Government has been giving active consideration to the situation of the oil industry in Canada for some time. It has had the benefit of a constructive report from the Royal Commission on Energy, and the National Energy Board has studied intensively the changing conditions which have characterized the period since the Commission reported.

I wish to inform the House that the Government has decided upon a national oil policy which is, briefly, to achieve target levels of production of oil, including natural gas liquids, which will be set from time to time, and which will be designed to reach approximately 800,000 barrels a day in 1963. This objective for 1963 can be achieved by the industry on an economically sound basis, and will be approximately as high as the figure which would be achieved if the Montreal pipeline were to be constructed.

The production target level for the first part of this period will be an average of 640,000 barrels a day for the year 1961, with a level of not less than 625,000 barrels a day to be attained by midyear. This compares with an average production of 550,000 barrels a day in 1960.

These targets are to be reached by increased use of Canadian oil in domestic markets, west of the Ottawa Valley, and by some expansion of export sales largely in existing markets which can be reached through established pipelines.

The growth in domestic use is predicated in particular on substituting in Ontario markets west of the Ottawa Valley, products refined from Canadian crude for those now supplied from foreign crude. This will require in Ontario the displacement of the present small imports of crude, and a progressive reduction in imports of foreign products and transfers of products refined from foreign crudes in Montreal. Refining capacity in Ontario will have to be increased over the period so that by 1963 capacity is sufficient to enable the Ontario market, west of the Ottawa Valley, to be supplied substantially from Canadian crudes.

The Government programme for expanded production of oil will be on a voluntary basis, but importers of crude and petroleum products will be required to report their imports monthly from January 1, 1961 in order to permit the National Energy Board to continue to assess the situation.

The increase in production of Canadian oil reflected in these target levels will, of course, require a sincere effort and full co-operation by all segments of the industry. The Government desires that this effort and co-operation will be forthcoming without formal regulation.

The Government has instructed the National Energy Board to evaluate the contribution of individual companies to the general efforts of the industry, as well as to report periodically on the progress of the programme. If this progress suggests that voluntary efforts are not producing the results anticipated, then the Government will take whatever further steps the circumstances may require to ensure the success of its policy, including the proclamation of Section 87 of the National Energy Board Act, which provides for the regulation of imports and exports of oil.

In developing its policy, the Government has full regard to the interests of other countries which might be affected by its decisions. Its present programme is designed to achieve the national objectives with the least possible disruption of normal trade patterns.

The increase in exports which is integral to the Government's programme is wholly consistent with the growth of sales of Canadian oil contemplated when exception from United States oil import controls was established, under which Canadian oil is relatively free to move into the United States by overland means of transportation.

The progressive displacement of imported crudes and products in the Ontario market is considered to be fully consistent with the public announcement of the Government of Venezuela that it considers that its oils should not reach these markets in the interior of Canada.

The United States Government has been made aware of the

Canadian Government's plan in view of the close connections between the oil economies of the two countries. Other interested governments are being informed today of the contents of the announcement which I have just made.

APPENDIX G

AN EVALUATION OF THE PORT OF CHURCHILL RELATIVE TO POTASH EXPORTS

The term potash is used to mean both the mineral form from which a stable compound of the element potassium can be extracted and also the compound itself. Potash has a wide variety of industrial uses but about 95 per cent of the world's output is used for the manufacture of fertilizers. (Potassium is one of the three major elements required in soil to sustain plant growth; the others are nitrogen and phosphorus.) The common form of potash used as a fertilizer is the compound potassium chloride (KCl) which is usually known as muriate of potash.

Muriate, when pure, can make available an oxidation 63.2 per cent potassium oxide (K_2O) by weight. But commercial muriate is not pure and normally provides only about 60 per cent K_2O. Prices are usually quoted for muriate on the basis of a 60 per cent content and this same basis is also normally used as the basis for expressing potash reserves, capacity, production, and consumption figures. But international trade statistics by volume, railway traffic and ocean shipments, are usually expressed on the basis of product tons.

The distinction between product tons and potash quantities expressed in terms of K_2O is important to avoid a misinterpretation of published estimates of potash volumes. Quantities expressed on one basis can be converted to the other if the K_2O content of the muriate is known; in practice, it is normal to assume a 60 per cent

content. Therefore, tons of muriate can be converted to K_2O equivalent by multiplying by 0.60 and quantities expressed in K_2O equivalent can be converted to muriate by multiplying by 1.67. Thus, Saskatchewan's 1967 output of potash, reported as 2.6 million tons on a K_2O basis, can also be expressed as 4.34 million tons of muriate (KCl). This larger quantity represents the actual tonnage of product to be shipped by the producers.

World Potash Reserves

Soluble potassium salts occur widely throughout the world. Large volumes are present in solution in surface and sub-surface waters but the most significant occurrences are underground beds formed by the evaporation of ancient bodies of salt water. Potash mining for use as a fertilizer commenced in Germany in the 1860's and until 1914 Germany supplied all North American requirements. During the war and the interwar period production of potash was started in other European countries and also, in 1931, in North America at Carlsbad in New Mexico.

World reserves of recoverable potash have been estimated at 136,000 million tons (K_2O equivalent), divided almost evenly between non-communist and communist countries. Saskatchewan's reserves alone are about 55,000 million tons, approximately 40 per cent of the world total and 80 per cent of the noncommunist total. These are immense tonnages in relation to present and prospective consumption, 15 million tons in 1967 and 32 million tons in 1978.

Even at the latter annual rate of consumption, known reserves would last over 4,000 years; even Saskatchewan's reserves alone would last the world for 2,500 years.

Estimates of world reserves are set out in Table 1. The wide geographic dispersion and the vast quantities of reserves are apparent. But production costs tend to be the principal criterion for the location of manufacturing facilities. The most economic production requires fertilizer to be manufactured near the cheapest sources of raw materials rather than in the region where it will be used. Thus, there is always likely to be an imbalance in the regional supply-demand relationship.

The potash deposits in Saskatchewan occur as part of the Prairie Evaporate Formation which stretches from northeastern Alberta, across Saskatchewan to western Manitoba and into North Dakota. Some permits have been issued in the other two provinces, but so far virtually all the potash activity has occurred in Saskatchewan in a belt about 120 miles wide running from just west of Saskatoon southeast to the Manitoba boundary.

Potash mineralization was first recognized in Saskatchewan in 1943 in cores from oil well drilling. This potash was too deep for exploitation but subsequent discoveries indicated rich commercial possibilities. Attempts to recover potash began in 1951 but very severe technical problems were encountered and it was not until the early 1960's that large scale continuous production was

TABLE 1

ESTIMATED WORLD POTASH RESERVES
IN MILLIONS OF TONS K_2O

North America	- Canada	55,000	
	United States	480	55,480
Western Europe	- West Germany	11,000	
	Spain	375	
	France	330	
	Italy	170	
	United Kingdom	150	
	Other Countries	30	12,055
Asia	- Jordan	700	
	Israel	600	
	India	20	1,320
Africa	- Morrocco	330	
	Other Countries	109	439
South America			40
NONCOMMUNIST COUNTRIES			69,334
Eastern Europe	- U.S.S.R.	55,000	
	East Germany	11,000	
	Poland	180	66,180
Asia	- China		1,000
COMMUNIST COUNTRIES			67,180
WORLD TOTAL			136,514

Source: Government of Saskatchewan
Potash Committee Report, July 1968.

commenced. Since then large and increasing quantities of potash have been shipped from Saskatchewan to world markets.

World Production and Consumption of Potash

The world potash situation has been transformed since the last war. But the changes have occurred in the supply-demand relationships, particularly on the supply side, rather than in production technology. And because of the widespread location and the size of known reserves, it is considered unlikely that there will be any serious challenge to present production methods in the foreseeable future.

On the demand side, there is clearly a need for greater fertilizer use to increase food production in the fact of rapid population growth. But fertilizer use is more a function of income levels and education than of population alone. Growth of world demand will, therefore, depend largely upon the availability of funds in the areas of need and upon the degree of agricultural enlightenment.

Throughout the postwar years to about 1960 the world growth rate for both consumption and production of potash averaged approximately 8 per cent a year. In the early 1960's the growth in consumption fell off to about 2 per cent but in the last few years growth has exceeded 10 per cent. Potash producers have responded to this recovery in consumption and almost all producing countries have increased their output. And the most striking increases have

have occurred in Canada, which means Saskatchewan. Production in Saskatchewan has grown from nothing ten years ago to more than $2\frac{1}{2}$ million tons in 1967. In that year the province produced more potash than France, West Germany, or East Germany, areas which for decades have been the world's principal suppliers of potash. Only the United States and the U.S.S.R. produced more potash in 1967 than Saskatchewan. By 1968 the province's capacity will exceed that of the United States and by the following year its capacity is expected to overtake that of the U.S.S.R. It seems likely that Saskatchewan will actually become the world's leading producer of potash by the end of 1968. In that year the province will probably account for about one-fifth of total world output and by the early 1970's for about one-third.

Numerous projections of world productive capacity and consumption of potash have been made by a number of different organizations such as the Department of Energy, Mines and Resources, U.S. Bureau of Mines, American Potash Institute, Tennessee Valley Authority, and United Nations agencies. There are considerable variations in detail between these projections; but because potash capacity and consumption are now large and well established, all projections produce broadly similar forecasts.

The most recently prepared projections available to us are those contained in the report issued in July 1968 by the Government of Saskatchewan's Potash Committee. This committee prepared detailed country by country estimates for the years to

TABLE 2

CONTINENTAL POTASH SUPPLY-DEMAND BALANCE
IN THOUSANDS OF TONS K_2O

	1968	1973	1978
North America	+1,895	+4,065	+1,100
Western Europe	+1,124	+ 485	- 525
Africa	- 240	+1,345	+1,115
Asia	- 760	- 930	-1,830
South America	- 205	- 195	- 405
Oceania	- 205	- 350	- 640
Miscellaneous	- 100	- 155	- 240
NONCOMMUNIST COUNTRIES	+1,504	+4,265	-1,425
Eastern Europe	+1,705	+1,620	-1,100
China	-	- 110	- 365
COMMUNIST COUNTRIES	+1,705	+1,510	-1,465
WORLD TOTAL	+3,209	+5,775	-2,890

Source: Government of Saskatchewan
Potash Committee Report, July 1968.

1978 of capacity and consumption. These have been summarized in Table 2 combining capacity and consumption estimates for each major region of the world to show the supply-demand balances by continent. Detailed continental estimates are shown in the preceding table.

In brief, the report demonstrates that production and consumption are highly concentrated in three areas, North America, Western Europe and Eastern Europe. In 1968 these three areas will account for 96 per cent of the world's production and 86 per cent of its consumption. Even ten years later, in 1978, the three areas are expected to account for more than four-fifths of the world totals. The table on the next page shows capacity and consumption estimates by area and their percentage distribution, in millions of tons K_2O equivalent, and the average annual growth forecast for consumption.

World Trade in Potash

International trade in potash is very large. Reported imports for the twenty-five principal countries covered by the United Nations statistics exceeded $250 million. And this figure excludes the trade of smaller countries, developing countries, and communist countries. Countries importing more than $10 million of potash in 1966 were United States ($64 million), Japan ($49 million), United Kingdom ($28 million), Netherlands ($13 million),

	Productive Capacity 1968 Million Tons	%	1978 Million Tons	%	Consumption 1968 Million Tons	%	1978 Million Tons	%	Av. Annual Growth %
North America	6.7	34	11.1	38	4.8	30	10.0	31	7.5
Western Europe	5.3	28	5.7	20	4.2	26	6.2	20	4.0
Eastern Europe	6.5	34	8.9	31	4.8	30	10.0	31	7.5
All Other Countries	0.7	4	3.2	11	2.2	14	5.6	18	10.0
WORLD TOTAL	19.2	100	28.9	100	16.0	100	31.8	100	7.0

and Yugoslavia ($12 million). Seven other countries showed imports of over $5 million in that year. As for the largest exporters reporting, for the first time in 1966 the list was headed by Canada ($70 million). The other large exporters exceeding $10 million in that year were West Germany ($55 million), France $37 million), Belgium ($35 million), and United States ($32 million). Belgium is not a producer of potash - her exports are the result of her very large entrepôt trade.

Canada's own official export statistics are shown in Table 3. Only since January 1966 has Canada published separate figures for muriate of potash; previously muriate was included with fertilizers n.e.s., but it must have represented most of that category. In 1967 Canadian exports reached $86 million but $59 million (69 per cent of the total) went to the United States and a further $10 million (11 per cent) went to Japan. Northwest Europe is shown in the U.N. statistics to have become an important export market in 1966. In that year Canadian exports to the

TABLE 3

CANADIAN POTASH EXPORTS BY COUNTRY OF DESTINATION
IN THOUSANDS OF DOLLARS

	1967	1966	1965	1964	1963
United States	58,923	53,389	40,981	23,047	16,016
Japan	10,060	11,713	9,356	8,081	6,486
Netherlands	9,165	5,378	6	-	-
India	3,320	19	-	-	-
New Zealand	1,655	3,387	1,459	390	-
South Korea	854	-	-	-	-
Taiwan	709	754	1,265	1,045	-
Malaysia	499	-	-	-	-
South Africa	434	318	-	-	-
Brazil	215	364	554	395	316
Puerto Rico	193	138	-	-	-
Australia	110	135	69	-	56
West Germany	6	-	-	-	-
Pakistan	-	275	-	-	-
Dominican Republic	-	193	-	-	-
Ceylon	-	134	-	-	-
Costa Rica	-	107	112	-	-
Phillipines	-	60	652	14	16
Other Countries	-	-	23	909	152
	86,143	76,365	54,478	33,881	23,133

Source: Dominion Bureau of Statistics, Trade of Canada.

Notes:

1. Exports reported above for 1967 and 1966 are muriate of potash (export classification 416-52) but figures for the three previous years are for the general classification 'fertilizers n.e.s.' (export classification 416-99). This included muriate, which is believed to have represented the greatest part of the classification.

2. All countries of destination in 1967 and 1966 are shown above. Exports to another sixteen countries were shown in the previous three years. The only significant quantities were: Cuba $905,000 in 1964 and United Kingdom $151,000 in 1963.

3. The above dollar values published by D.B.S. differ from those published in U.N. publications because of the respective units employed - U.S. dollars in U.N. publications and Canadian dollars in D.B.S. publications.

Netherlands were valued at $5 million and in 1967 at $9 million. Late in 1967 IMC announced that the company had negotiated a contract to supply one million tons of potash to the United Kingdom over a five-year period. Canada is, however, unlikely to export potash to the United Kingdom for more than a small number of years. It has recently been announced that potash production is to start in Yorkshire and that the United Kingdom will then herself become an exporter.

Factors Affecting the Shipment of Saskatchewan Potash

Saskatchewan is fortunate in having potash reserves which are both very large and of high quality in comparison with most other regions. As the province's industry is new it can be assumed that it has incorporated into its plant equipment all the latest technological advances. Consequently Saskatchewan mining techniques and benefication processes result in unit costs comparable to or lower than costs anywhere else in the world. Saskatchewan potash should, therefore, be extremely competitive on the North American continent and only slightly less competitive on the world market. But one of the big uncertainties in the world situation is the policies of the U.S.S.R. and the Eastern European countries with respect to exporting potash to the rest of the world. After 1945 and until Canadian production became available, these countries were among the largest suppliers of potash to world markets.

The biggest nonproduction cost associated with the marketing of potash is transportation. The Saskatchewan Potash Committee reports that the $9.00 per ton freight rate for moving muriate to Vancouver represents roughly one-third of the cost of potash at Vancouver. The Committee also reports that transportation represents an even larger proportion of the cost of muriate laid down in the American mid-west. Of a total cost of $35.75, $16.25 or 45 per cent is attributable to transportation.

These freight rates do not put the Saskatchewan industry at a serious competitive disadvantage with U.S. mines in New Mexico as they face very similar transportation costs to the midwest and the Pacific coast. But in the years ahead when capacity substantially exceeds demand, the cost of transportation may significantly affect the competitive position of Saskatchewan potash in world markets.

One important factor which tends to keep rail freight rates for potash in Canada fairly high is the seasonal demand for the product and so for the hopper cars in which it is shipped. One solution to smoothing out shipments from the mines is storage facilities, either at the point of export or in the consumption areas. Integrated storage facilities for all producers would achieve the maximum economies. But as the various companies are very concerned with product differentiation for market purposes, some of the possible economies might have to be foregone.

The Saskatchewan Committee estimated that transportation cost savings in Canada could amount to between 10 and 30 per cent with a smoother flow of potash and the use of continuous integrated trains. Other significant opportunities for rail cost saving could arise from reverse shipments, running loaded both to and from Saskatchewan.

A complete alternative to rail transportation is pipe-lining which appears technically feasible. At this stage the economies are uncertain but it appears that a line for potash and sulphur using oil as the carrier is the most promising. The use of a pipline would virtually dictate the establishment of massive storage facilities at the point of export or use.

One very real fear voiced by the Saskatchewan Committee concerns charges of dumping in the U.S. market. Any substantial price reductions resulting from lower transportation costs would probably make the New Mexico mines uneconomic and leave Saskatchewan producers vulnerable to U.S. quota restrictions.

Potential Exports Through Churchill

Since no potash rail movement to the Port of Churchill nor ocean movement from the Port exist, forwarding costs via Churchill are unavailable. Even if transportation cost material were available it would seem most unlikely that any advantage in utilizing the Port of Churchill could be demonstrated. The ocean distance from the Port of Churchill to potential markets favour Pacific ports.

TABLE 4

DISTANCES IN NAUTICAL MILES

To	From Churchill	Vancouver	Montreal
Rio de Janeiro	6,410	8,345[a]	5,331
Buenos Aires	7,936	8,336[b]	6,421
Valparaiso	7,079[a]	5,922	5,798
Yokohama	12,172[c]	4,260	10,885[a]
Singapore	10,598	7,078	10,129[c]
Calcutta	10,252[c]	8,639	9,783
Karachi	8,424[c]	10,199	7,955[c]

Source: "Distance Tables for Mariners" published by Geo. Philip and Son (1960).

[a]Via Suez Canal.

[b]Via Strait of Magellan.

[c]Via Panama Canal.

Admittedly, fairly large sales were reported in 1966 and 1967 and again in the first half of the current year to the Netherlands. But it has already been pointed out that Europe will have excess potash productive capacity at least to 1973 - and this was true even before the announcement in the summer of 1968 of new production plans in Britain. Excess capacity in the short run and immense reserves make it virtually certain that Europe will be a

net exporter and not a market for Canadian potash.

Canada's principal markets for potash have been and are likely to continue to be in the United States, particularly the midwest. These markets are naturally served by rail. Some potash has actually gone to the United States through Vancouver but under a special arrangement. These shipments are destined for the south-eastern states and the vessel involved makes the return trip to Vancouver with a cargo of phosphate rock.

Apart from rail shipments to the United States, most Canadian potash destined for export travels first to Vancouver. Approximate rail distances from the Saskatoon-Regina area are 1,075 miles to Vancouver, 825 miles to Churchill and to Fort William, and 1,750 miles to Montreal. Thus Churchill is about the same distance from the potash producing area as Fort William and enjoys an advantage over the other two ports - about 250 miles over Vancouver and about 900 miles over Montreal. The present rates for potash from Saskatchewan are $9.00 per ton to Vancouver, $11.20 to Fort William, $17.40 to Montreal, and $21.20 to Halifax. On this basis the rail rate from the potash producing areas to Churchill could be $5.60 per ton if based on existing Vancouver rates, $6.80 if related to the Fort William rate, or $9.00 if related to the Montreal rate. As the Vancouver rate appears to be predicated on regular train load movements, it does not seem likely that it would apply to Churchill. The most probable rate for potash to Churchill is one comparable to the Montreal rate. At $9.00 per

ton, Churchill would enjoy no rail freight advantage over Vancouver.

Even more uncertainty exists about possible ocean freight rates for potash shipped through Churchill. Distance travelled is not the only factor in the cost of operating an ocean vessel as most expenses are time-related. However, in the absence of more specific information, it is reasonable to assume that a comparison of ocean freight rates from Churchill with rates from Vancouver or Montreal will reflect the relative distances. This is particularly true as relatively long distances are involved to all potential overseas markets.

The competitive position of Churchill to Vancouver or Montreal is suggested by the fact that there is no port anywhere in the world which is closer to Churchill than to either of the other two ports, Vancouver or Montreal. On the basis of ocean distance alone, Churchill has the least disadvantage to northwest Europe, already ruled out as a significant market area for potash, and to the eastern side of the Indian peninsula. Towards Calcutta or Singapore, Vancouver has a clear distance advantage. As for South America, the east side is far closer to Montreal and the west side to Vancouver.

One comment about the Suez Canal should be made on these distance comparisons. Distance comparisons above assume the Suez route where this is shorter. It seems reasonable to expect that the canal will be reopened in due course, and its depth should not

be a problem as ships used in the potash trade are not exceptionally large.

Even though firm estimates of rail and ocean freight rates are not available, the locations of Canadian overseas potash markets make shipment from Churchill quite unpromising. This conclusion is based simply on relative distance without even considering the short season, high insurance rates, the lack of inbound cargo, and the generally unfavourable attitude of shippers to the Port of Churchill.

TABLE 1

WORLD IMPORT TRADE IN POTASH
IN THOUSAND OF U.S. DOLLARS

Imports	1966	1965	1964	1963
United States	63,849	48,126	33,497	9,967
Canada	1,955	2,360	2,669	2,726
Belgium	37,635	42,735	41,358	40,365
France	2,927	3,924	3,514	3,121
West Germany	1,282	1,597	1,158	1,259
Italy	8,280	6,493	6,418	5,034
Netherlands	13,425	14,106	12,489	7,960
United Kingdom	28,425	30,053	29,168	29,758
Denmark	8,462	10,460	10,220	10,301
Norway	6,420	4,930	4,853	4,098
Sweden	7,129	8,177	7,295	6,557
Portugal	952	1,366	946	864
Switzerland	884	555	107	97
Iceland	527	650	412	166
Ireland	7,482	7,546	7,452	7,584
Greece	1,632	2,030	1,022	1,208
Turkey	237	418	-	-
Spain	77	64	-	63
Finland	7,389	9,035	6,483	5,309
Yugoslavia	12,296	7,297	15,914	-
Australia	3,957	-	3,631	2,360
New Zealand	6,413	7,309	-	-
Japan	48,692	45,022	43,025	42,934
TOTALS	270,327	254,253	232,631	181,731

Source: U.N. World Trade Annual 1963-66.

Notes:

1. Reported imports of 'potassic fertilizers and materials' (SITC classification 561.3) which includes muriate of potash.

2. Data cover only 25 countries -- smaller countries, developing countries, and communist countries do not report.

TABLE 2

WORLD EXPORT TRADE IN POTASH
IN THOUSAND OF U.S. DOLLARS

Exports	1966	1965	1964	1963
United States	31,878	33,809	28,492	20,421
Canada	70,637	50,397	-	-
Belgium	35,095	38,984	38,734	42,432
France	37,001	40,193	43,856	39,005
West Germany	55,395	64,701	48,639	48,481
Italy	6,193	6,170	4,633	3,276
Netherlands	82	86	55	68
Spain	15,380	13,563	10,399	8,369
Japan	261	1,077	469	439
TOTALS	251,922	249,700	164,878	162,491

Source: U.N. World Trade Annual 1963-66.

Notes:

1. Reported exports of 'potassic fertilizers and materials' (SITC classification 561.3) which includes muriate of potash.

2. Data cover only 25 countries -- smaller countries, developing countries, and communist countries do not report.

TABLE 3

ESTIMATED POTASH PRODUCTION CAPACITY BY COUNTRY
IN THOUSANDS OF TONS K_2O

	1968	1973	1978
Canada	3,620	7,840	8,040
United States	3,075	3,140	3,045
North America	6,695	10,980	11,085
West Germany	2,500	2,500	2,500
France	2,000	2,000	2,000
Spain	550	700	800
Italy	280	400	400
Other Countries	4	5	5
Western Europe	5,334	5,605	5,705
Morrocco	-	600	600
Ethiopia	-	600	600
Congo	-	500	500
Libya	-	30	30
Africa	-	1,730	1,730
Israel	425	600	600
Jordan	-	170	350
India	5	30	60
Asia	430	800	1,010
Brazil	-	70	70
Peru	-	70	70
Chile	15	15	15
South America	15	155	155
NON-COMMUNIST COUNTRIES	12,474	19,270	19,685
U.S.S.R.	4,000	6,000	6,400
East Germany	2,400	2,400	2,400
Poland	60	60	60
Eastern Europe	6,460	8,460	8,860
China	250	350	350
COMMUNIST COUNTRIES	6,710	8,810	9,210
WORLD TOTAL	19,184	28,080	28,895

Source: Government of Saskatchewan - Potash Committee Report, July 1968.

TABLE 4

ESTIMATED POTASH CONSUMPTION BY COUNTRY
IN THOUSANDS OF TONS K_2O

	1967	1968	1973	1978
Canada	195	210	300	430
United States	4,100	4,410	6,325	9,080
Mexico	170	185	290	475
North America	4,465	4,805	6,915	9,985
Western Europe	4,050	4,210	5,120	6,230
Africa	220	240	385	615
Japan	705	725	835	965
India	145	175	430	1,075
Pakistan	15	20	55	160
Korea	110	120	185	290
Taiwan	55	60	90	140
Phillipines	60	65	100	155
Near East	20	25	35	55
	1,110	1,190	1,730	2,840
South America	200	220	350	560
Australia	85	90	170	350
New Zealand	105	115	180	290
Oceania	190	205	350	640
Miscellaneous	90	100	155	240
NON-COMMUNIST COUNTRIES	10,325	10,970	15,005	21,110
U.S.S.R.	2,090	2,300	3,705	5,965
Other Countries	2,340	2,455	3,135	3,995
Eastern Europe	4,430	4,755	6,840	9,960
China	200	250	460	715
COMMUNIST COUNTRIES	4,630	5,005	7,300	10,675
WORLD TOTAL	14,955	15,975	22,305	31,785

Source: Government of Saskatchewan - Potash Committee Report, July 1968.

TABLE 5

ESTIMATED NORTH AMERICAN POTASH PRODUCTION CAPACITY
IN THOUSANDS OF TONS K_2O

	1968	1973	1978
Saskatchewan			
I.M.C. (Esterhazy)	2,000	2,100	2,100
Allan (Allan)	300	900	900
Noranda (Viscount)	-	900	900
Cominco (Vanscoy)	720	720	720
Kalium (Belle Plaine)	600	600	600
Alwinsal (Lanigan)	200	600	600
Duval (Saskatoon)	200	600	600
Sylvite (Rocanville)	-	600	600
P.C.A. (Saskatoon)	420	420	420
New Mine (--?--)	-	400	600
	3,620	7,840	8,040
United States			
Carlsbad	2,375	2,280	2,155
Other Areas	700	860	890
	3,075	3,140	3,045
NORTH AMERICA	6,695	10,980	11,085

Source: Government of Saskatchewan - Potash Committee Report, July 1968.

APPENDIX H

BULK CARGO

Coal, all types
Crude Petroleum
Fuel Oil
Lubricating Oil and Greases
Gasoline
Rye, Oats and Other Grains
Barley
Corn
Wheat
Soybeans
Sugar
Fertilizer
Logs, Round Timber
Lumber and Timber
Wood Pulp
Coke
Slag Dross By Product
Tar Pitch and Creosote
Coal Petro-Products nes
Petro Coal Products nes
Soybean Oil
Pulpwood
Fluorspar and Other Non-Metallic Minerals, Crude
Phosphate Rock
Aluminum Ore and Concentrates
Iron Ore and Concentrates
Manganese Ore
Metallic Ores and Concentrates nes
Iron and Steel Scrap
Limestone
Crushed Stone
Sand and Gravel
Lead Ore and Concentrates
Zinc Ore and Concentrates
Asbestoes Unmilled
Gypsum
Sulphur

TABLE 1

FOREIGN CARGO UNLOADINGS, PORT OF CHURCHILL, 1958-1967
(000) tons

Commodity / Year	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Fuel Oil	16.7	31.1	31.6	29.0	33.4	49.8	36.2	-	14.2	19.0
Gasoline	12.1	5.3	35.5	3.7	16.2	6.3	-	18.3	-	0.7
Distilled Alcholic Beverages	0.5	0.7	0.6	0.2	0.4	0.3	0.3	0.4	0.9	0.6
Rubber Fabricated Materials	-	-	-	-	-	-	-	-	0.3	-
Bricks, Tiles, n.e.s.	-	-	17.6	0.6	0.5	0.5	0.2	0.5	0.6	-
Machinery, n.e.s.	0.4	0.7	0.3	-	0.7	-	-	-	0.1	-
Miscellaneous End Products	-	-	-	-	-	-	-	-	0.7	-
Passenger Automobiles and Chassis	0.1	0.1	-	-	-	-	-	-	0.1	-
Structural Shape and Steel Piling	-	-	-	-	-	-	-	-	-	2.1
Structural Class	0.7	0.6	0.4	0.4	0.2	0.2	0.3	0.2	-	-
Chemicals	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	-	-
General Cargo	1.1	3.5	1.6	0.9	1.1	0.5	0.7	0.8	0.6	2.1
Total Unloaded	31.7	42.1	71.9	35.0	52.7	57.7	37.8	20.3	17.5	24.6
Per Cent of Total Canadian Unloadings	0.10	0.12	0.18	0.14	0.13	0.13	0.08	0.04	0.03	N.A.

Source: For 1958-1966, D.B.S. 53-203: totals, General Cargo, Fuel Oil, Gasoline for all years; and all commodities for 1966. 1967: National Harbours Board, 1967 Supplement to the Annual Report. For all other specific commodities, 1958-1965, Dalgleish.